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PLANING CHARACTERISTICS OF SIX SURFACES REPRESENTATIVE
OF HYDRO-SKI FORMS

By Kenneth L. Wadlin and John R. McGehee

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

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WASHINGTON
February 10, 1950

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AUTHORITY: NACA RESEARCH ABSTRACT NO. 111

EFFECTIVE DATE: JANUARY 10, 1957

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RESEARCH MEMORANDUM

PLANING CHARACTERISTICS OF SIX SURFACES REPRESENTATIVE
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SUMMARY

The planing characteristics, as determined by tank tests, are presented for six surfaces representative of hydro-ski forms. Two of the surfaces had rectangular plan forms with convex and concave-convex bottom cross sections, respectively. Two had triangular plan forms with longitudinal taper ratios of 4:1 and 2:1, and with flat and convex cross sections, respectively. The remaining two surfaces had combined rectangular and triangular plan forms with 4:1 and 2:1 taper ratios, respectively, and with flat bottom cross sections.

The tests were made at trims from 4° to 20° , speeds from 15 to 35 feet per second, and sufficient loads to define variations with wetted length.

The data for each surface are given in the form of plots of wetted length, load, resistance, trimming moment, and draft against wetted area. Plots of wetted area forward of the observed wetted length at the chine are also included.

INTRODUCTION

The use of retractable planing surfaces, called hydro-skis, for supporting jet-propelled water-based airplanes during the high-speed part of their take-offs and landings was proposed in reference 1. The results of some preliminary tests of models fitted with hydro-skis are presented in references 1 and 2.

Although some planing data are available for flat rectangular surfaces, for instance, references 3 and 4, the fundamental data required for the design of hydro-skis and hydro-ski arrangements are limited. The hydrodynamic characteristics of a series of forms suitable for hydro-skis are therefore being determined in Langley tank no. 2.

The series includes cross sections suitable for flush retraction into fuselages and wings, one cross section considered suitable for operation on snow and ice, and pointed plan forms indicated to be desirable for landing stability in the tests of reference 1. The upper surfaces are faired for subsequent investigation of the submerged and emerging conditions as well as the planing conditions.

The planing data for three of the surfaces have been presented in reference 5. This paper provides corresponding data for six additional surfaces in the series. As in reference 5, the data are given without analysis or discussion to make the results immediately available.

MODELS AND APPARATUS

The principal details of the models tested are given in figures 1 to 6. Model 250C had a transversely curved bottom with a 30° central angle and was rectangular in plan form. Model 250E had a flat bottom and was triangular in plan form with a longitudinal taper ratio of 4:1. Model 250F had a transversely curved bottom of a constant radius corresponding to a 60° central angle at the leading edge and was triangular in plan form with a taper ratio of 2:1. Model 250G had a flat bottom, and in plan form the model had a rectangular forward section and a triangular aft section with a taper ratio of 4:1. Model 250H had a flat bottom, and in plan form the model had a rectangular forward section and a triangular aft section with a taper ratio of 2:1. Model 250J was rectangular in plan form with a concave-convex transversely curved bottom for snow and ice operation.

All triangular models were tested with the apex of the triangle aft. All the models had the same plan-form area (0.347 sq ft) and were made of solid mahogany. The upper surfaces of all the models were arbitrarily faired by making all the longitudinal sections circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

The present tests were made by using the small model towing gear on the Langley tank no. 2 towing carriage as were the tests of reference 5. In an effort to improve the accuracy of the data, however, a wind screen was installed to reduce the aerodynamic tares to negligible values. A photograph of the setup with the wind screen removed to show the gear is given in figure 7. The wind screen consisted of two vee-shaped shields in tandem in front of the model extending to within three-eighths of an inch of the water surface.

The density of the water during these tests was 63.3 pounds per cubic foot and the kinematic viscosity was 1.143×10^{-5} square feet per second at 70° F.

PROCEDURE

The tests consisted of towing the models in the water at various speeds and loads at fixed trims (τ) of 4° , 8° , 12° , 16° , and 20° . A sufficient number of loads were chosen at each trim to define the variations of resistance, trimming moment, and draft with wetted length. The maximum speed was determined by the measuring limits of the equipment and ranged from 30 to 35 feet per second. The minimum speed was 15 feet per second since below this speed consistent planing data could not be obtained. Resistance, trimming moment, draft, and wetted length were measured.

Draft is defined as the depth of the trailing edge of the model below the undisturbed water surface. Trimming moment was measured about a point above the model and, from the measured results, the trimming moment about the trailing edge at the center line of the model was calculated.

The wetted length observed was the distance from the trailing edge of the model to the intersection of the dynamic solid-water boundary with the chine of the model. The wetted length at the center line was determined from underwater photographs similar to those in figure 8.

The wetted area is defined as the plan-form area wetted by the dynamic solid water. This area was determined from the plan form of the models, the observed wetted length at the chine, and the additional wetted area forward of the observed wetted length determined from the underwater photographs of the dynamic water line.

RESULTS

The results are presented in figures 9 to 40 as set forth in table I.

From the procedure described, the quantities in the figures are defined as follows:

- (a) Resistance is the measured horizontal force.
- (b) Trimming moment is the measured trimming moment referred to the trailing edge of the model.
- (c) The load is the unbalanced weight of the model and gear.

(d) Draft is the depth of the trailing edge of the model below the free-water surface.

(e) Wetted area is the plan-form area wetted by the dynamic solid water.

(f) Wetted length is the observed length from the trailing edge of the model to the intersection of the dynamic solid-water boundary with the chine or center line.

It should be noted that while the wind screen effectively eliminated the aerodynamic tares, it also largely eliminated the influence of the air stream on the wave patterns around the models. Though it is believed that this influence can be considered negligible for practical design purposes, it results in the data being not strictly comparable with those of reference 5.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

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1. Dawson, John R., and Wadlin, Kenneth L.: Preliminary Tank Tests of NACA Hydro-Skis for High-Speed Airplanes. NACA RM L7I04, 1947.
2. Wadlin, Kenneth L., and Ramsen, John A.: Tank Spray Tests of a Jet-Powered Model Fitted with NACA Hydro-Skis. NACA RM L8B18, 1948.
3. Shoemaker, James M.: Tank Tests of Flat and V-Bottom Planing Surfaces. NACA TN 509, 1934.
4. Sottorf, W.: Analysis of Experimental Investigations of the Planing Process on the Surface of Water. NACA TM 1061, 1944.
5. Wadlin, Kenneth L., and McGehee, John R.: Planing Characteristics of Three Surfaces Representative of Hydro-Ski Forms. NACA RM L9C03, 1949.

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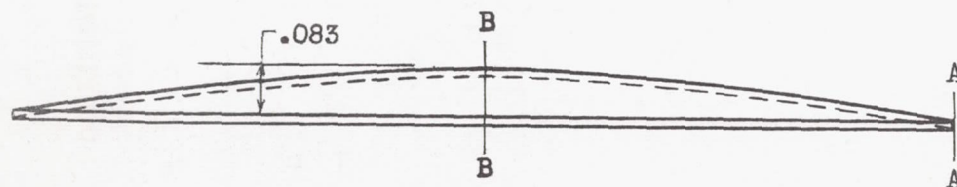
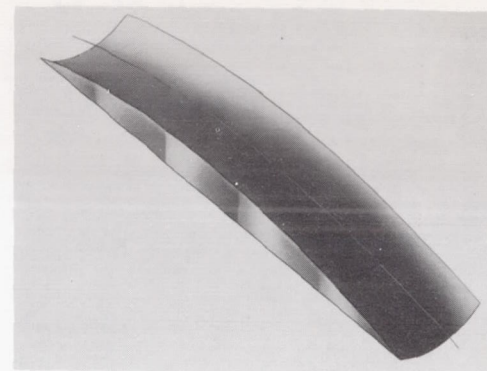
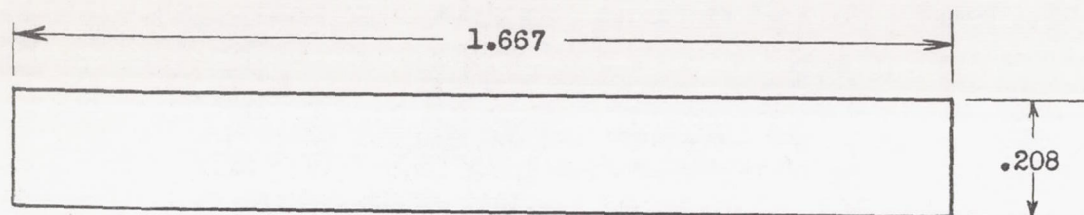
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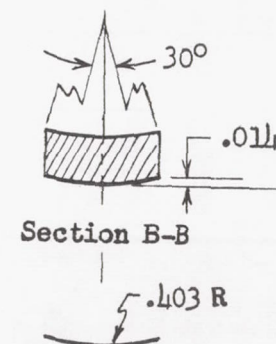
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The NACA logo, which consists of the word "NACA" in a stylized font inside a wing-like shape.

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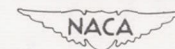


All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.



Section B-B

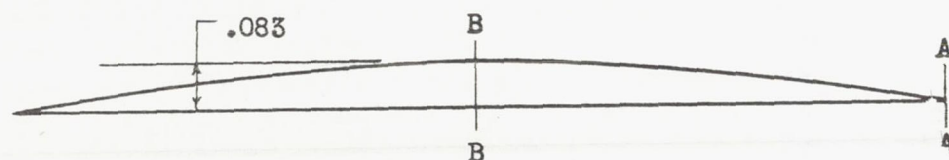
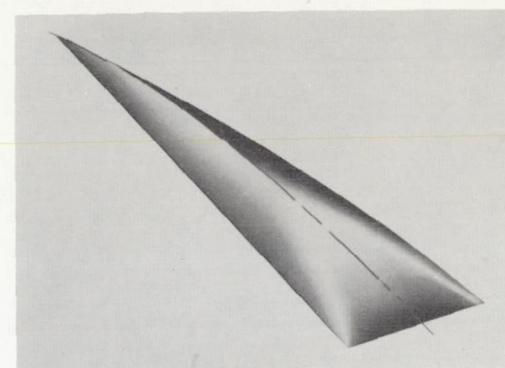
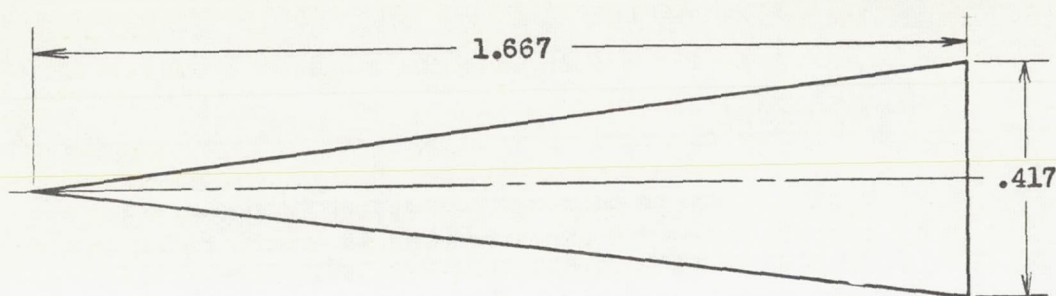
Section A-A



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Figure 1.- Details of rectangular planing surface with convex transverse bottom curvature (model 250C).
(All dimensions are in feet.)

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Section A-A



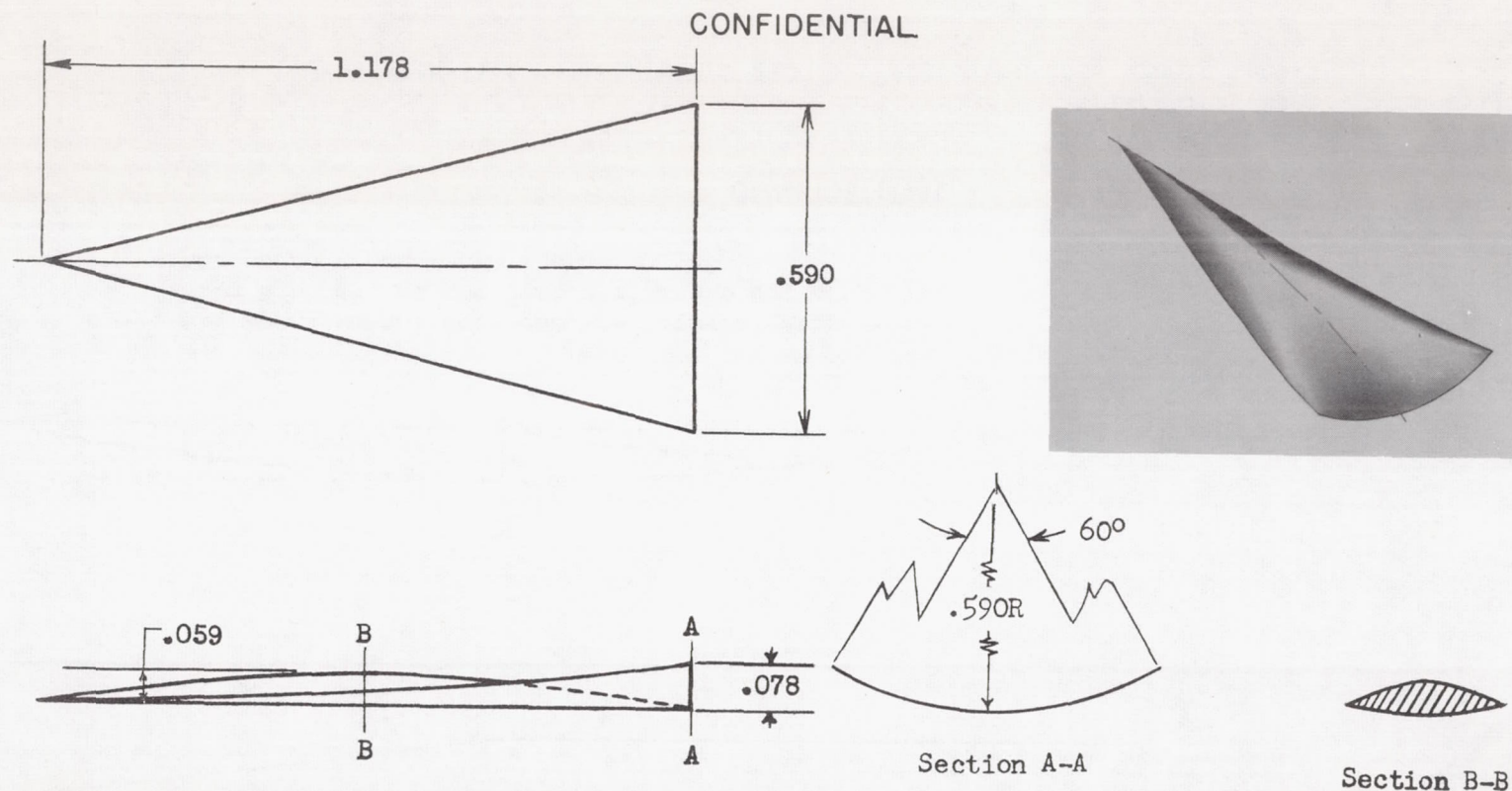
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All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

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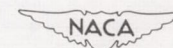
Figure 2.- Details of triangular planing surface with flat bottom (model 250E).
(All dimensions are in feet)

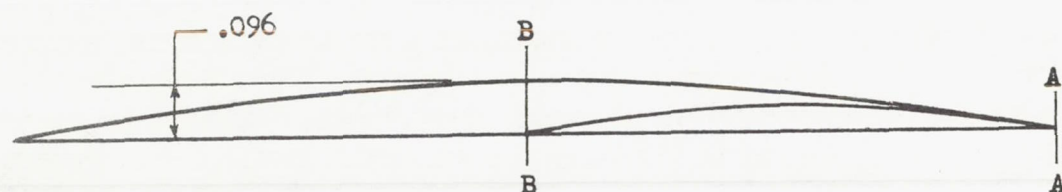
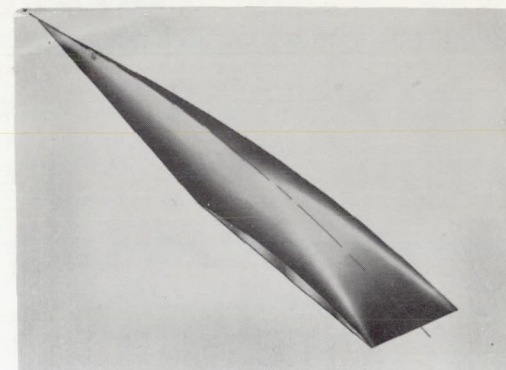
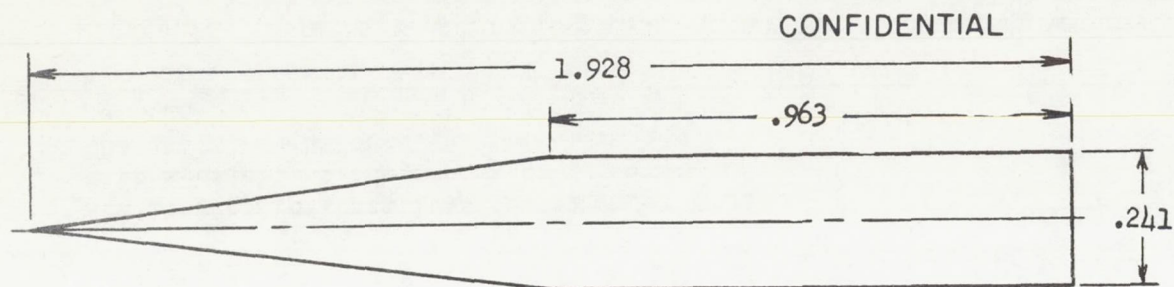


All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

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Figure 3.- Details of triangular planing surface with convex transverse bottom curvature (model 250F).
(All dimensions are in feet.)





Section A-A



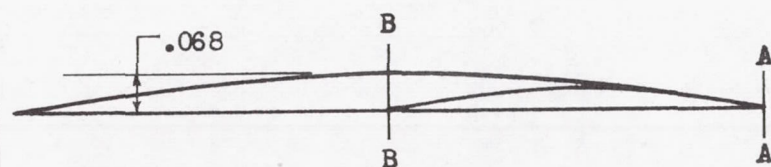
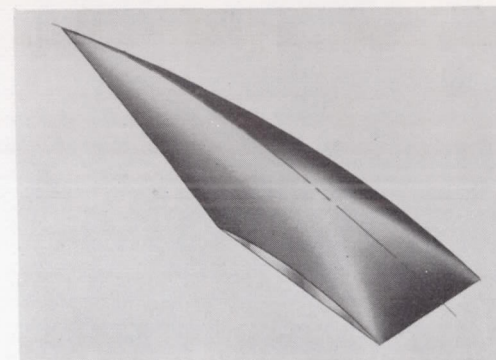
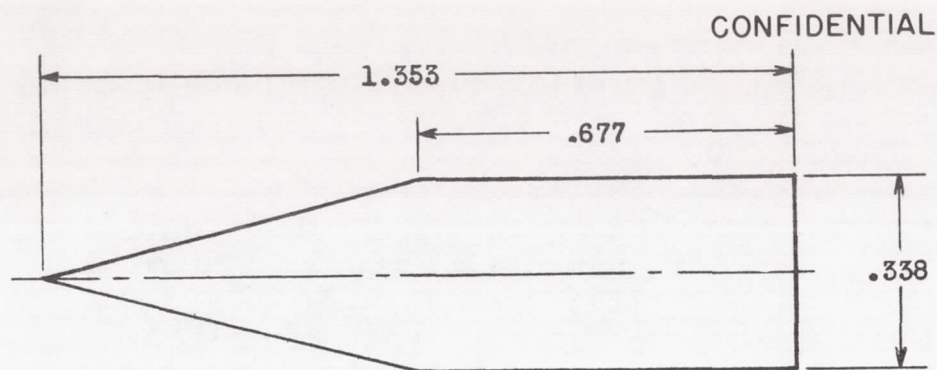
Section B-B

All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

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Figure 4.- Details of planing surface of combined rectangular and triangular (taper ratio 4:1) plan forms with flat bottom (model 250G). (All dimensions are in feet.)



All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.

Section A-A



Section B-B

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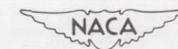
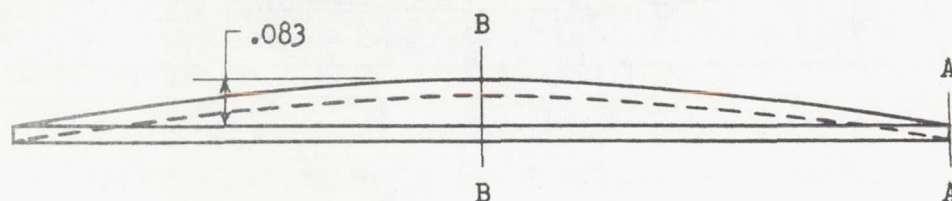
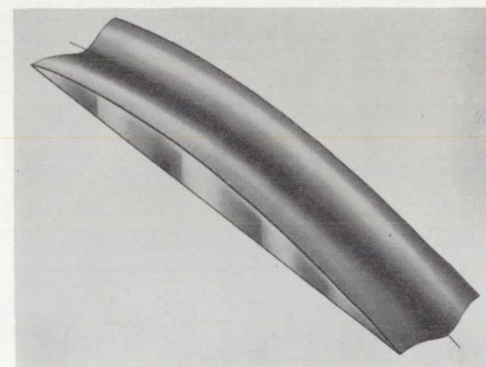
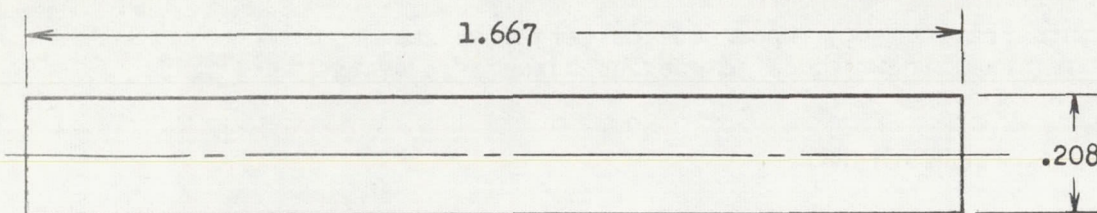
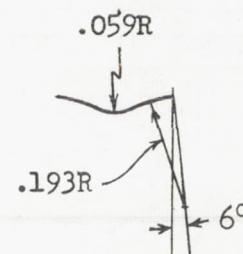


Figure 5.- Details of planing surface of combined rectangular and triangular (taper ratio 2:1) plan forms with flat bottom (model 250H). (All dimensions are in feet.)

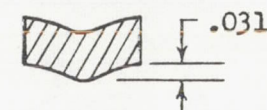
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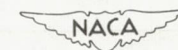
All longitudinal sections are circular arcs with a height at the center of 5 percent of the chord which forms the bottom of the section.



Section A-A



Section B-B



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Figure 6.- Details of rectangular planing surface with a concave-convex transverse bottom curvature (model 250J).
(All dimensions are in feet.)

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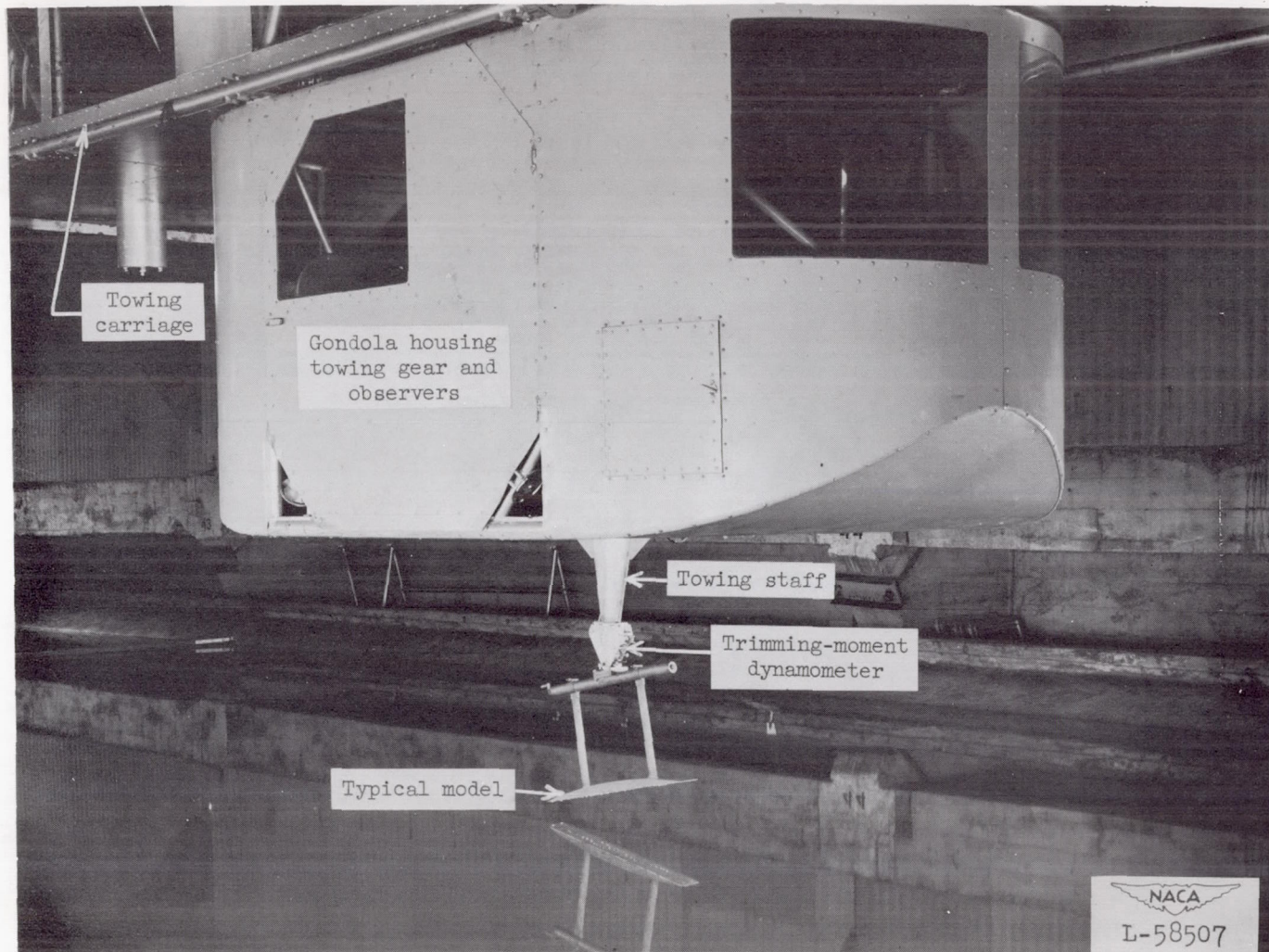
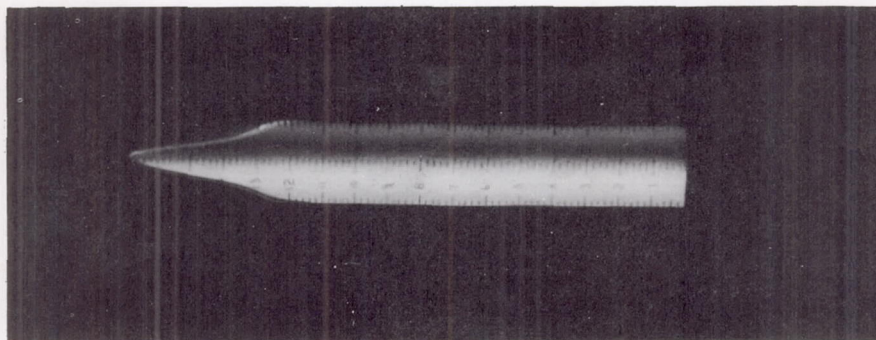


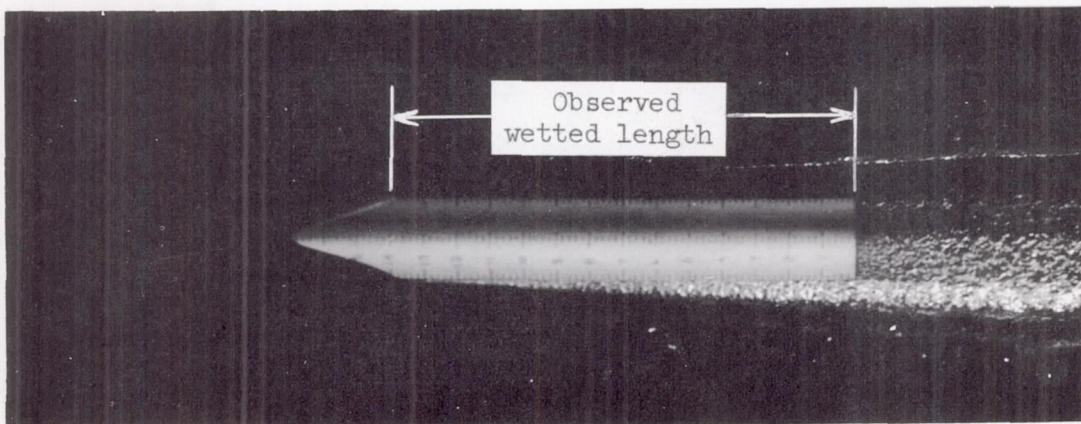
Figure 7.- Photograph of test setup with wind screen removed.

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Typical static water line



Typical dynamic water line



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Figure 8.- Underwater photographs of model 250J at trim of 4° .
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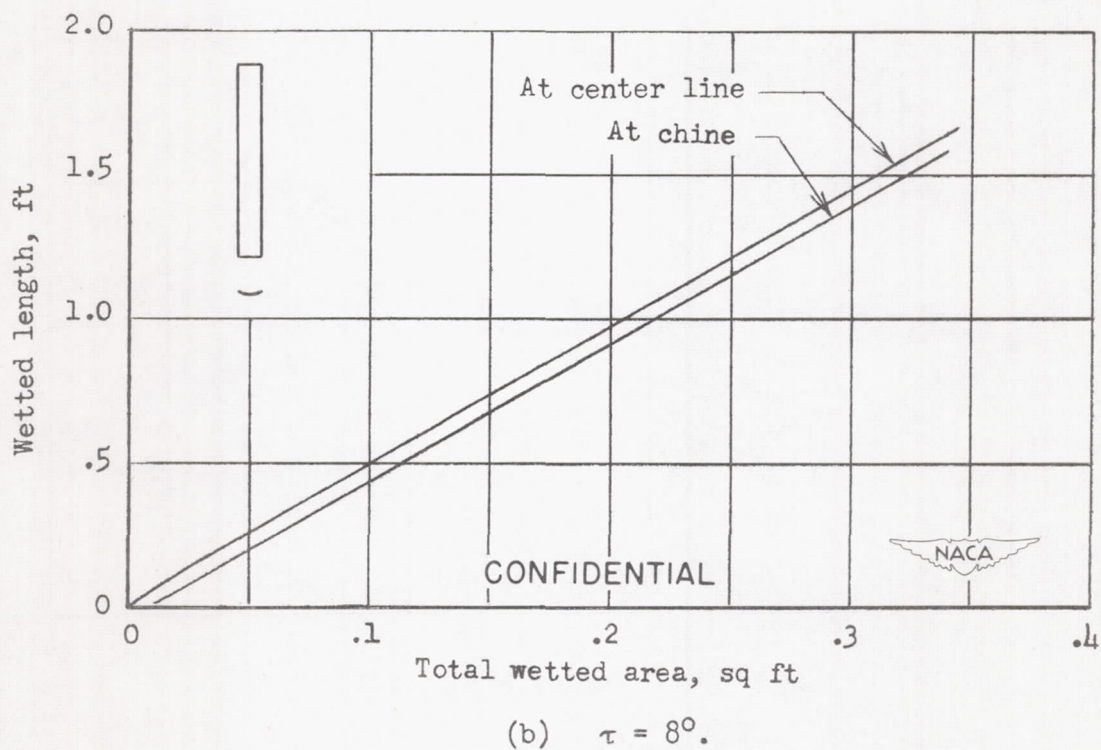
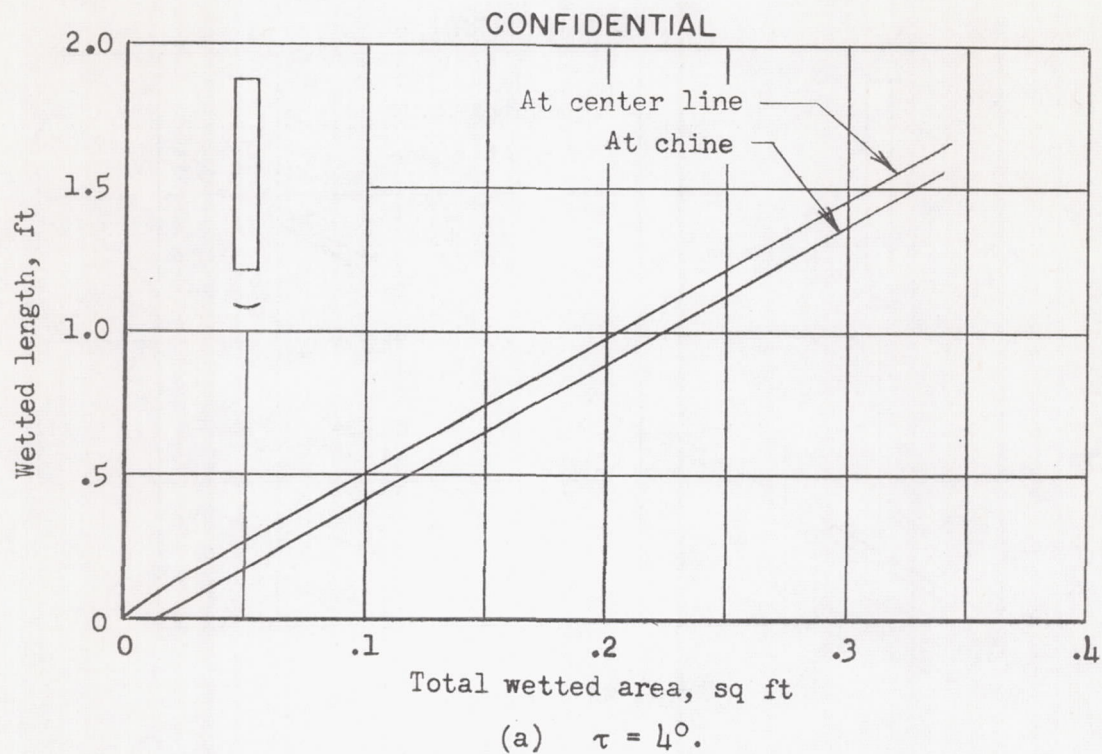


Figure 9.- Variation of wetted lengths at chine and at model center line with wetted area for model 250C.

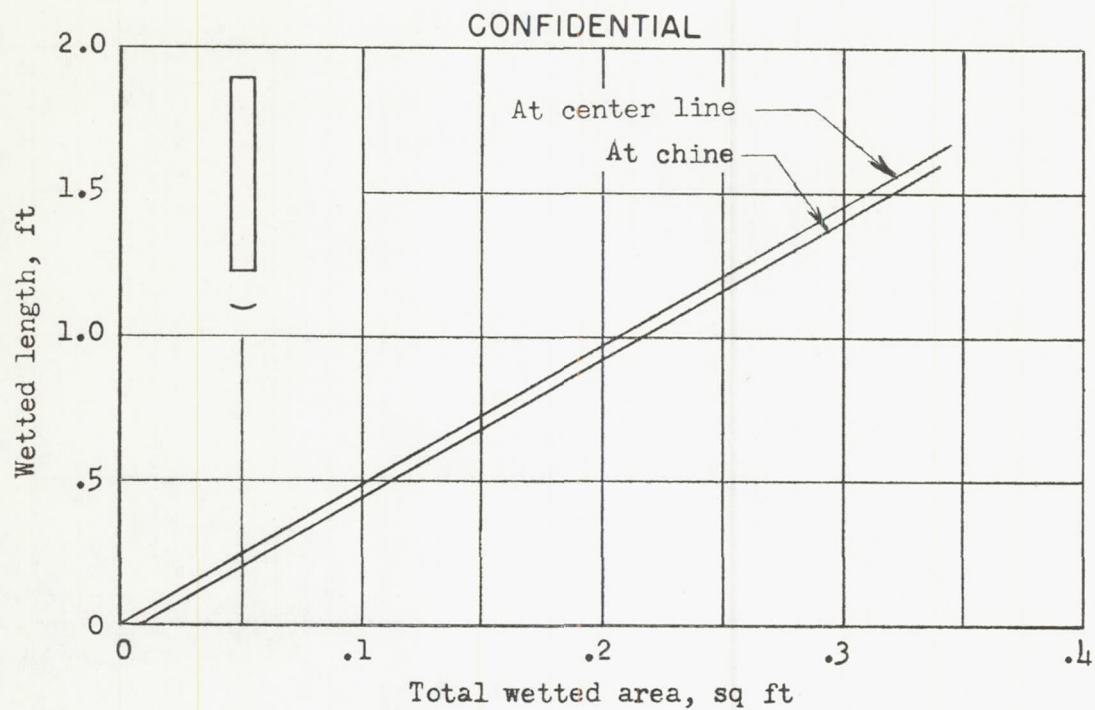
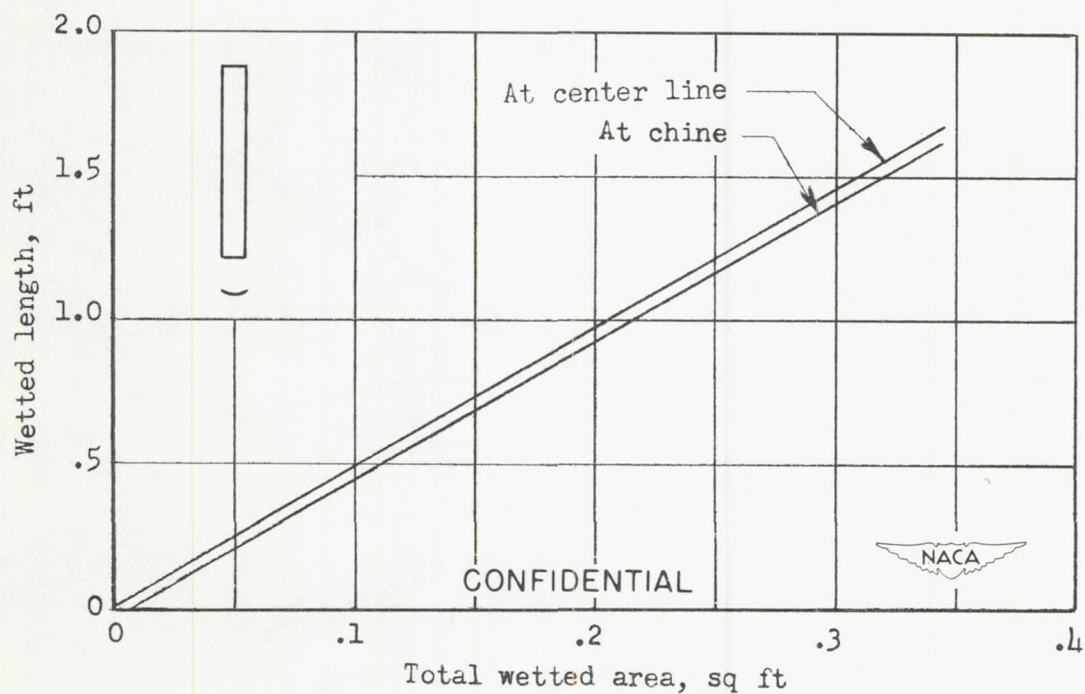
(c) $\tau = 12^\circ$.(d) $\tau = 16^\circ$.

Figure 9.- Continued.

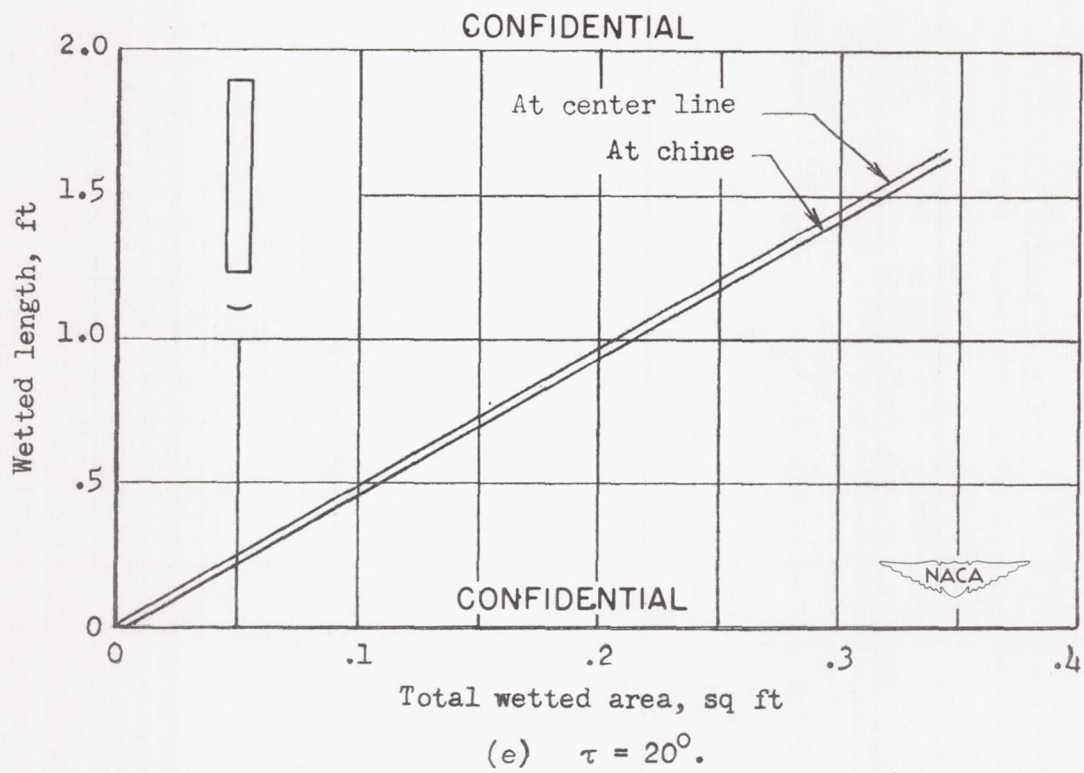


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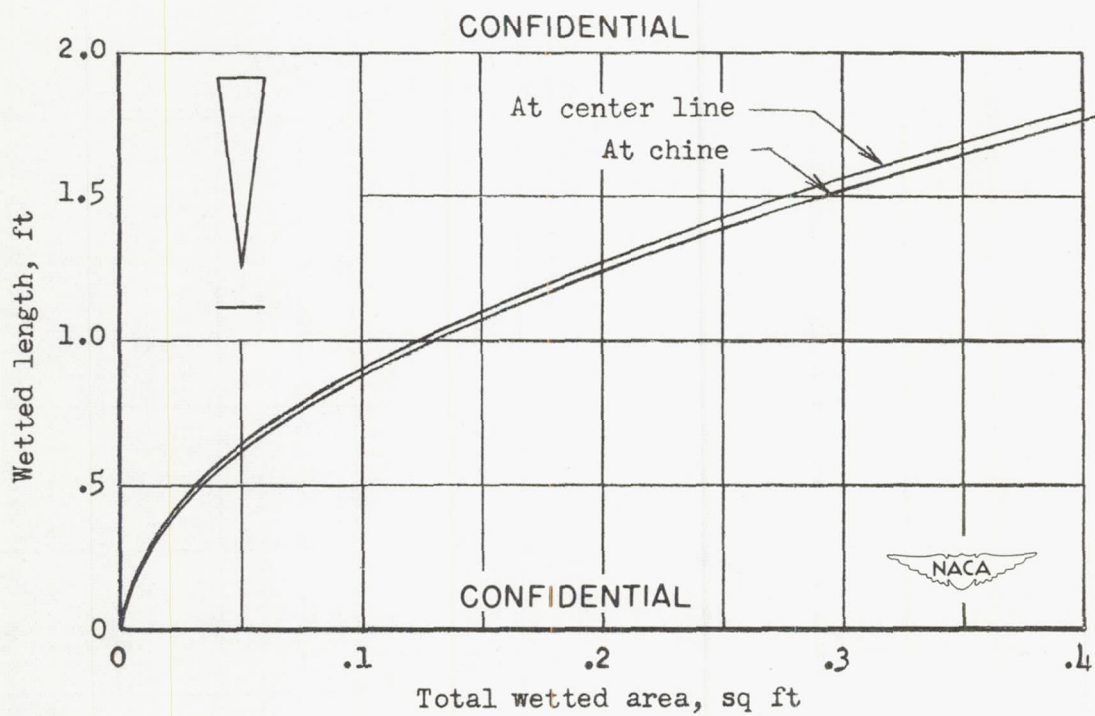
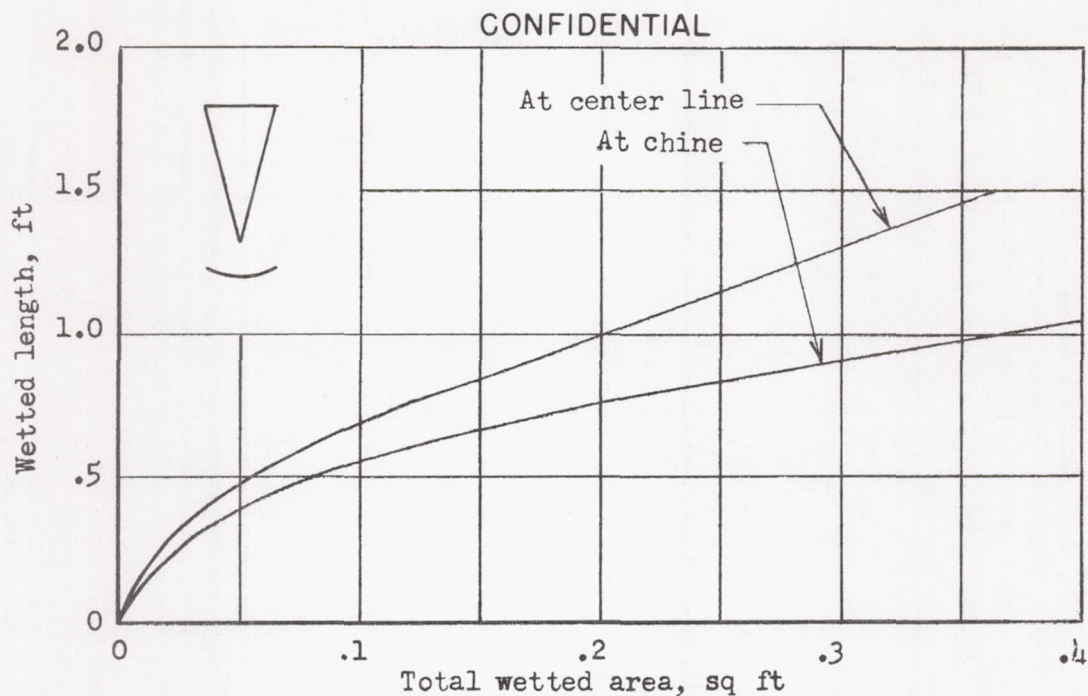
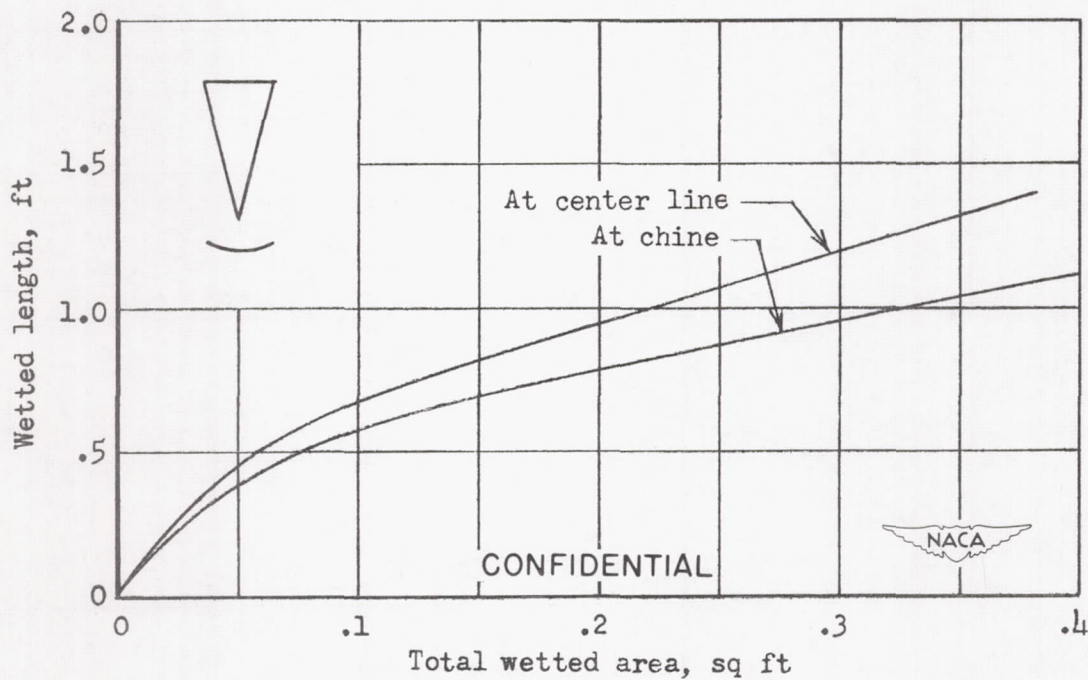


Figure 10.- Variation of wetted lengths at chine and at model center line with wetted area for model 250E.

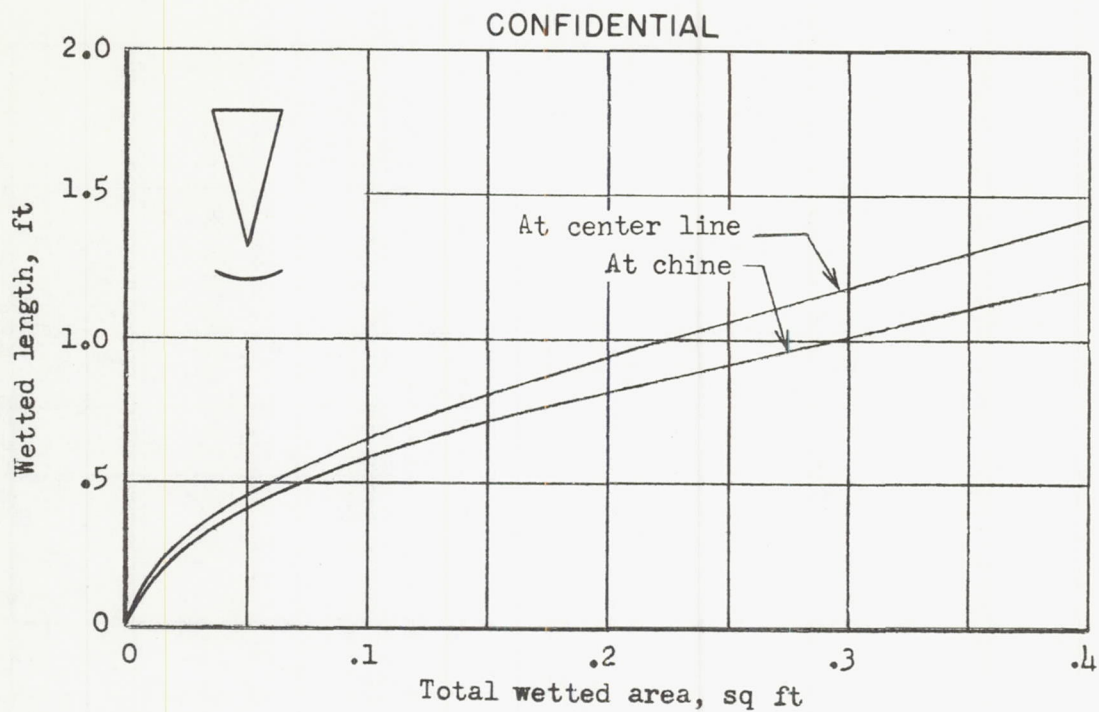


(a) $\tau = 4^\circ$.

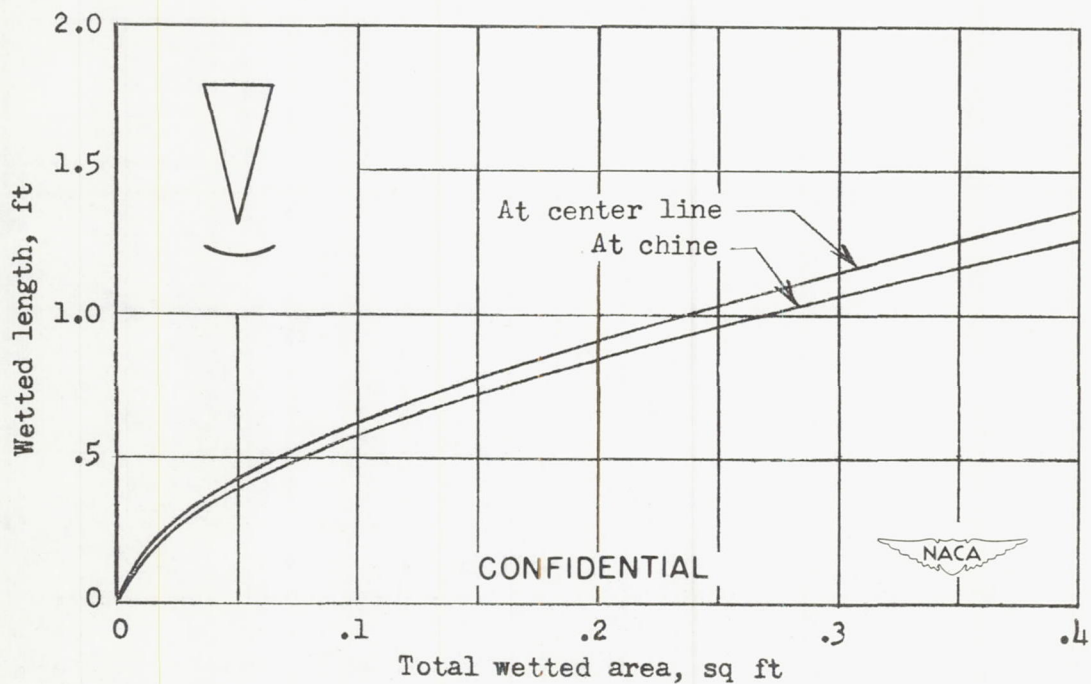


(b) $\tau = 8^\circ$.

Figure 11.- Variation of wetted lengths at chine and at model center line with wetted area for model 250F.



(c) $\tau = 12^\circ$.



(d) $\tau = 16^\circ$.

Figure 11.- Continued.

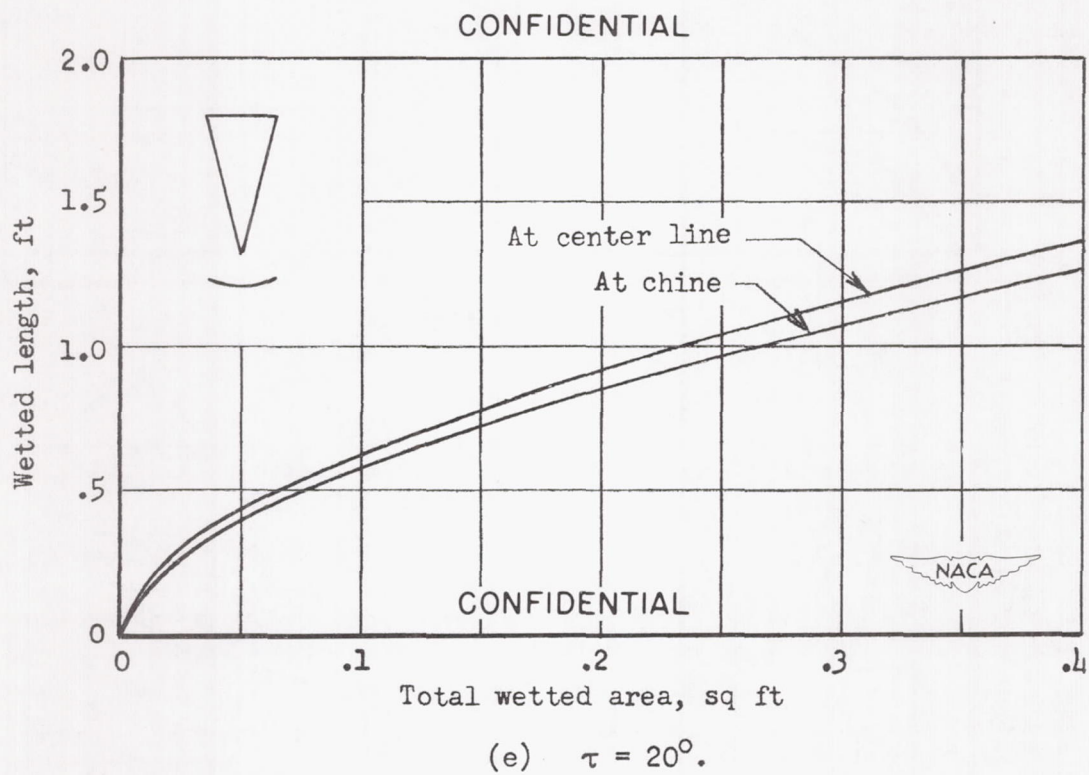
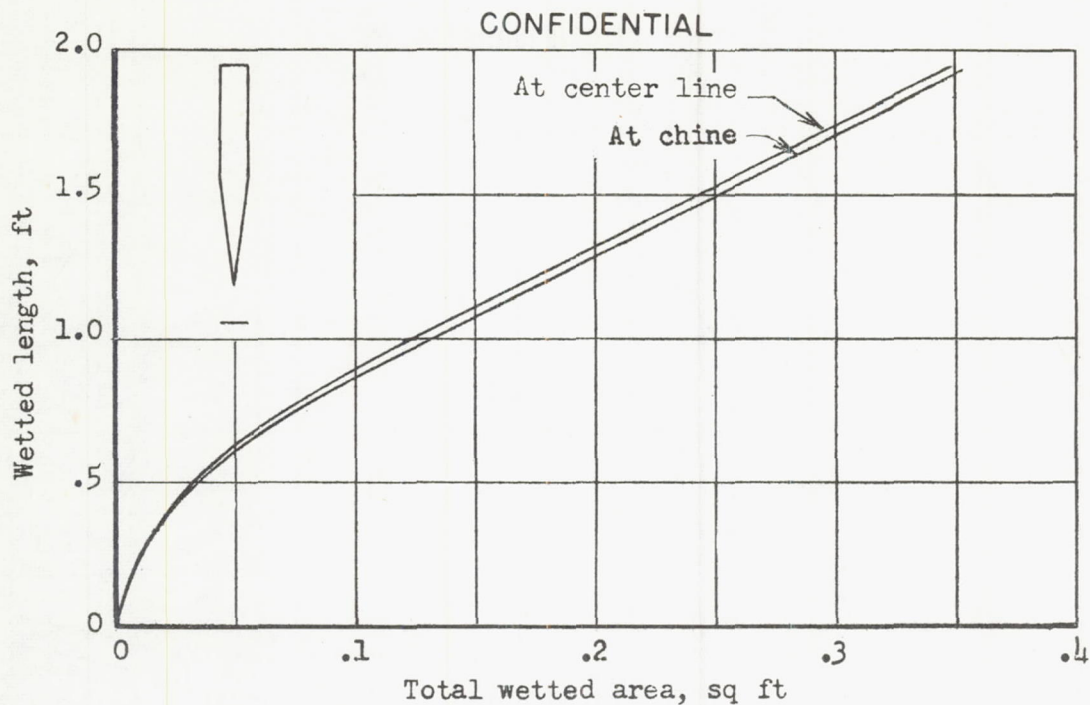
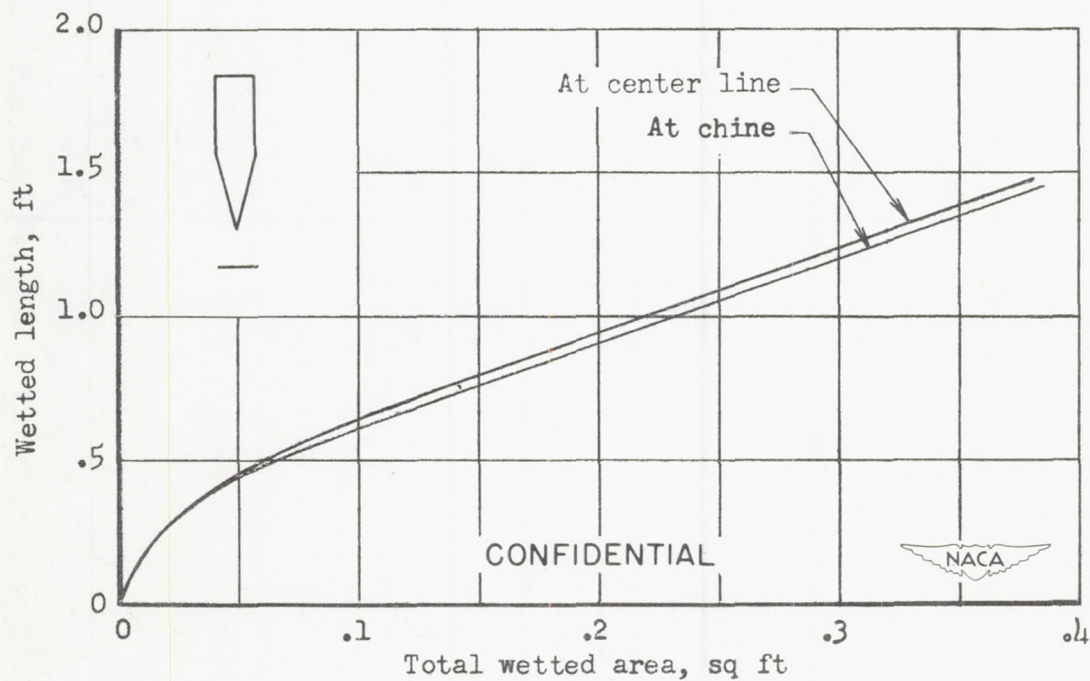


Figure 11.- Concluded.



(a) Model 250G.



(b) Model 250H.

Figure 12.- Variation of wetted lengths at chine and at model center line with wetted area for models 250G and 250H.

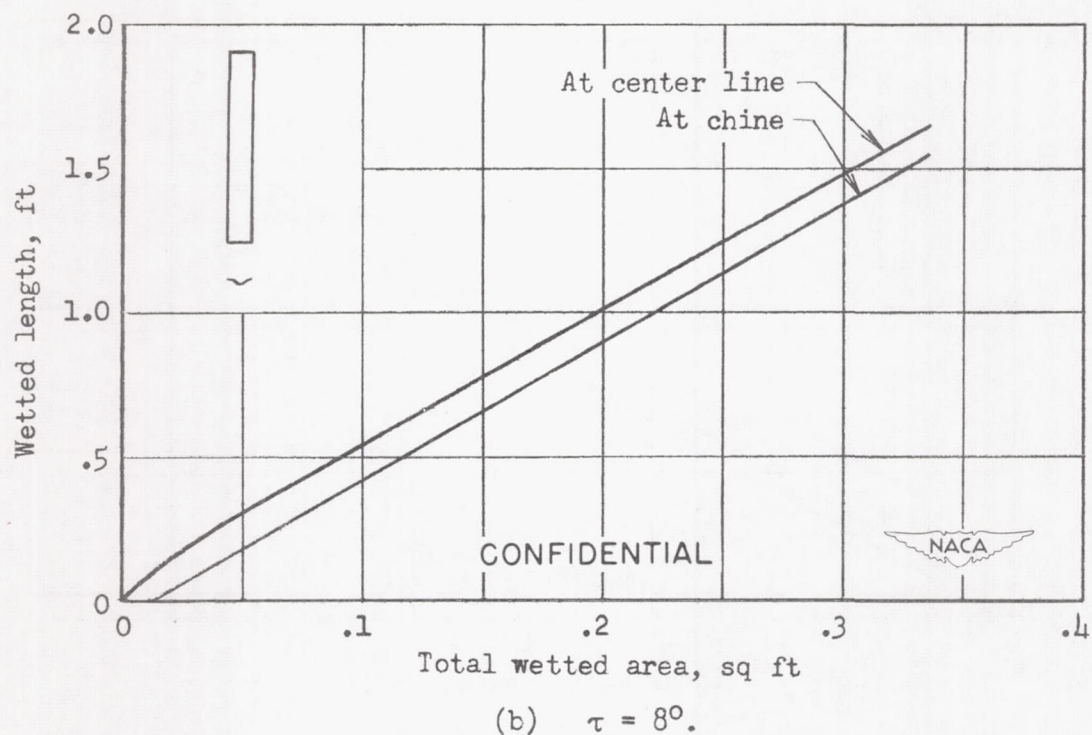
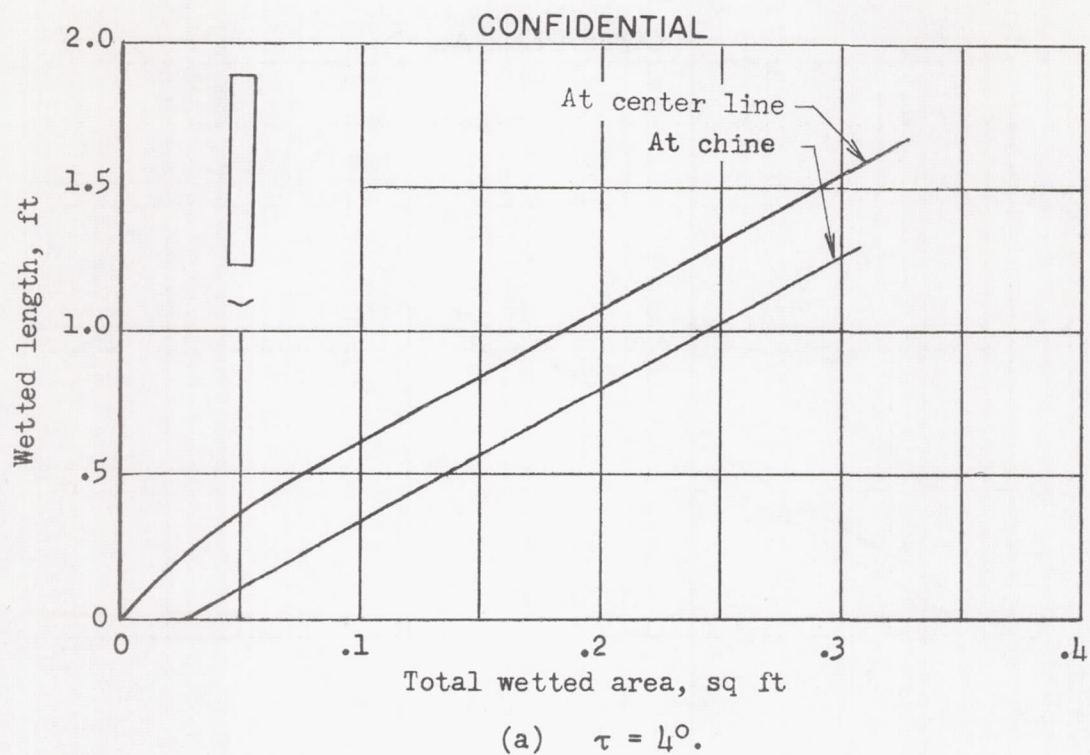


Figure 13.- Variation of wetted lengths at chine and at model center line with wetted area for model 250J.

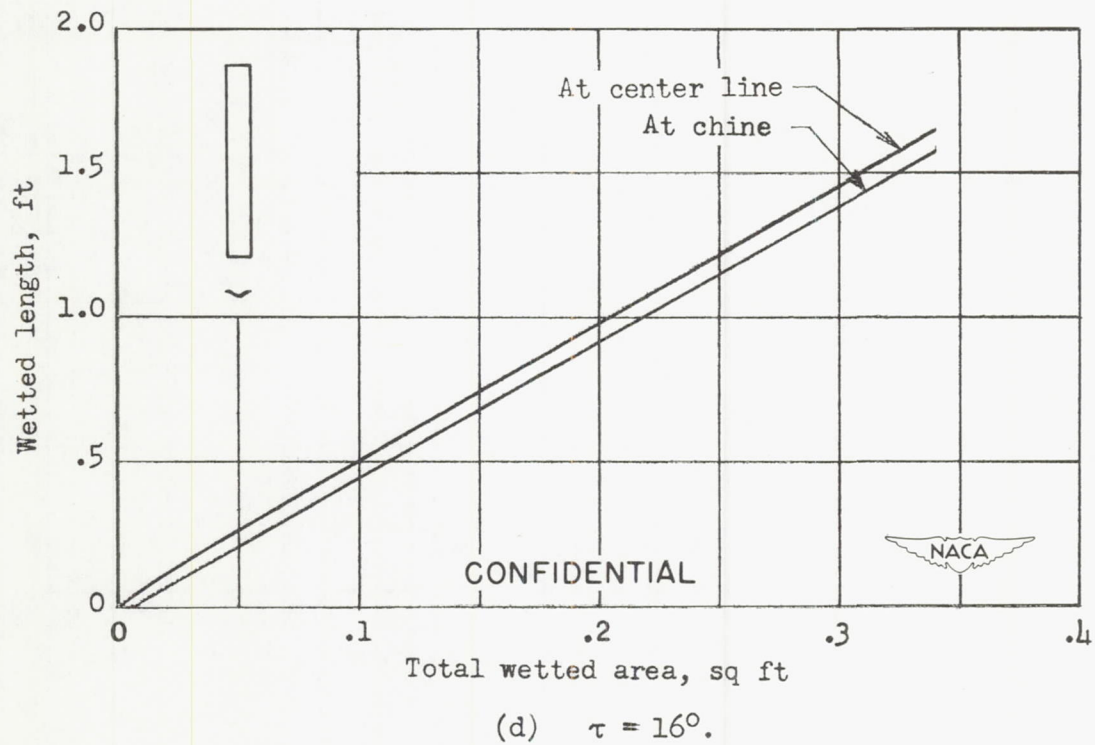
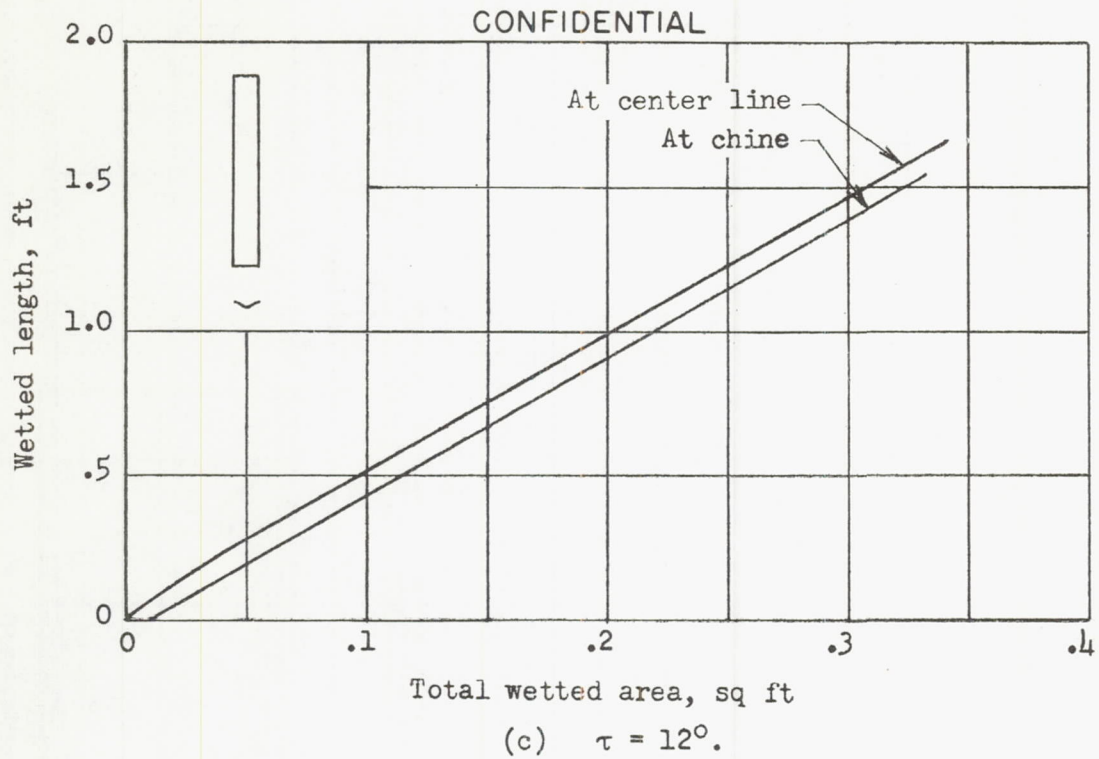


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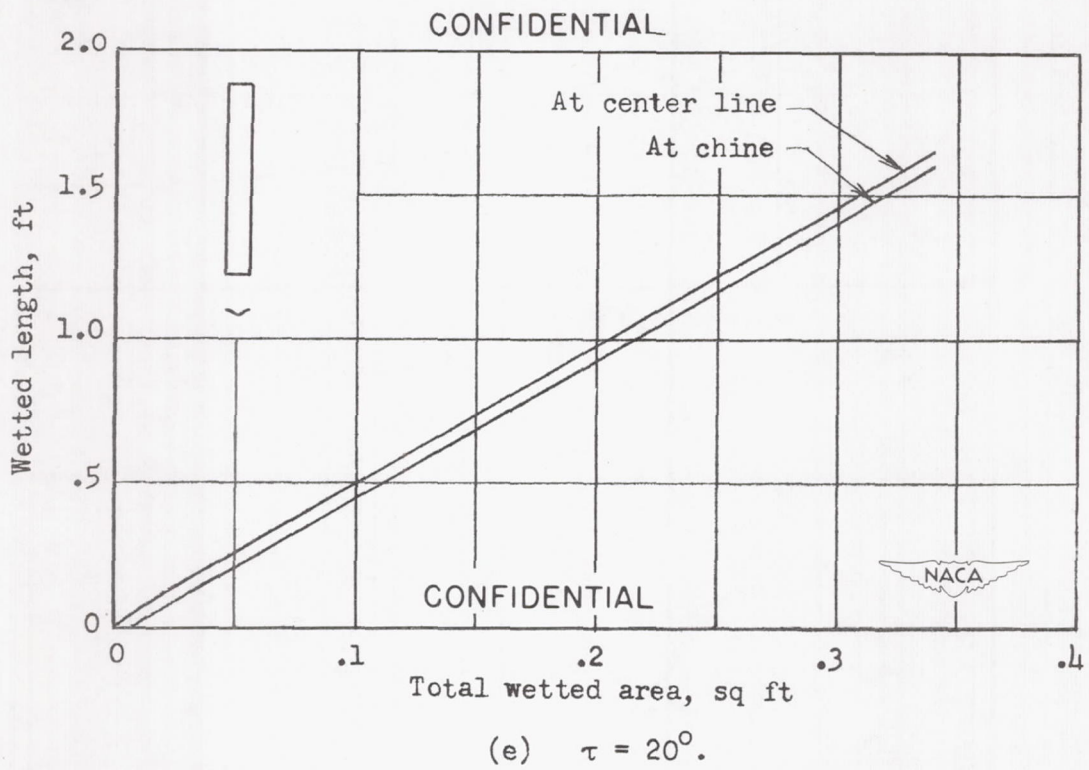
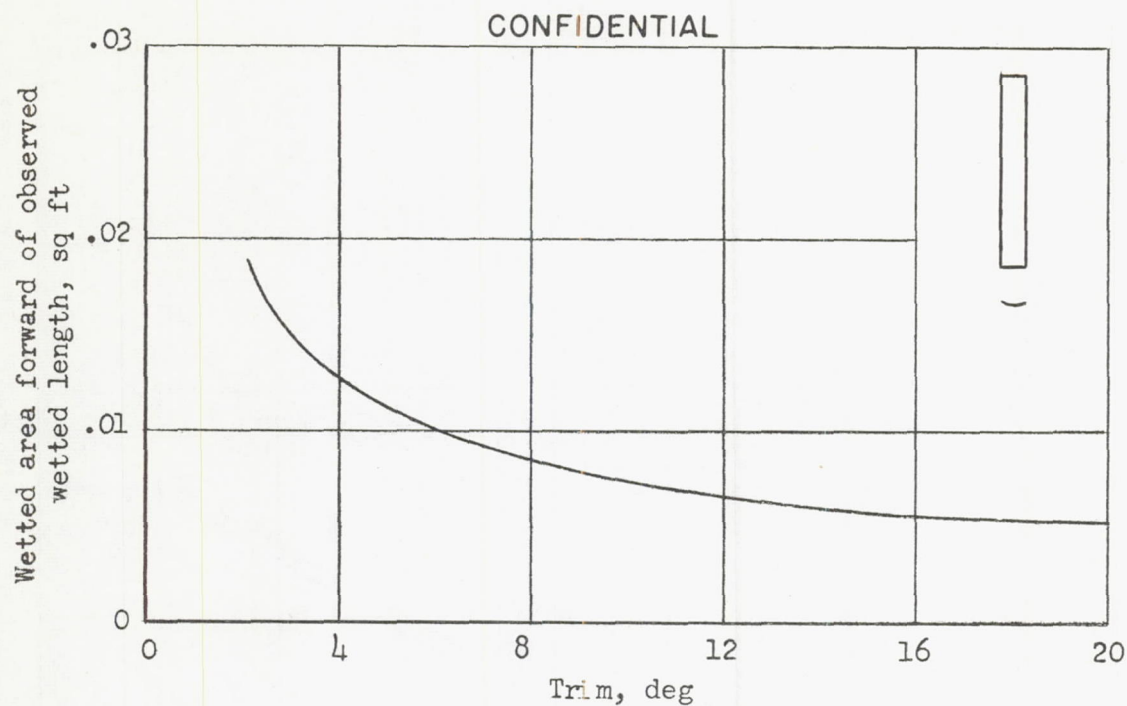
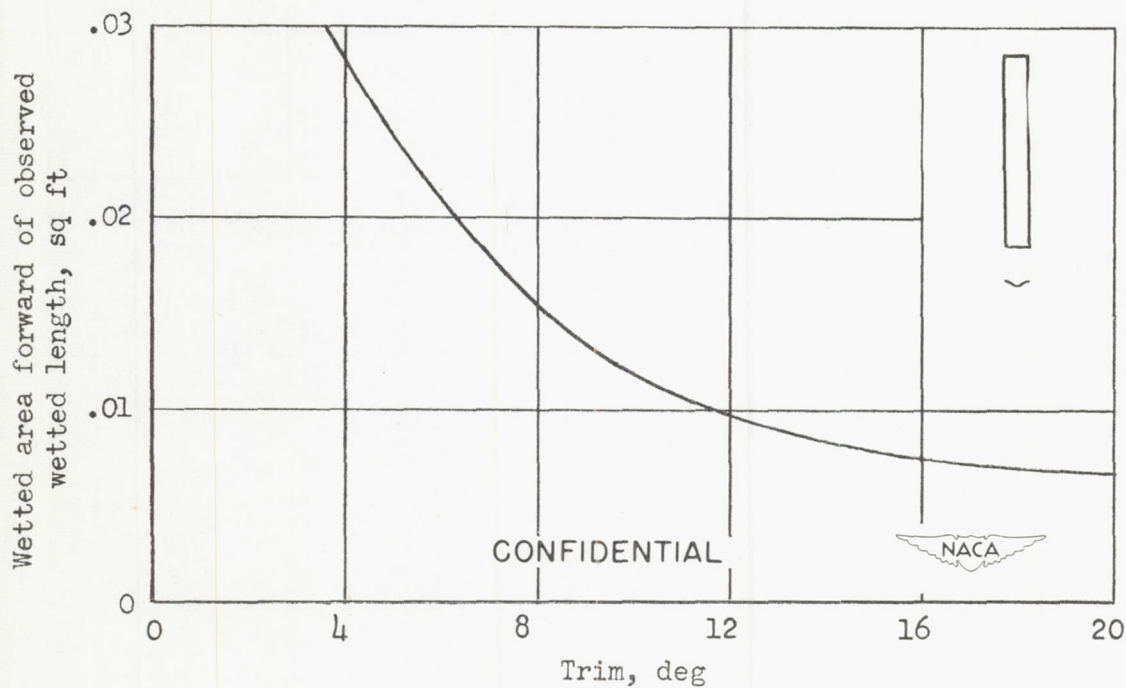


Figure 13.- Concluded.



(a) Model 250C.



(b) Model 250J.

Figure 14.- Wetted area forward of the observed wetted length for models 250C and 250J.

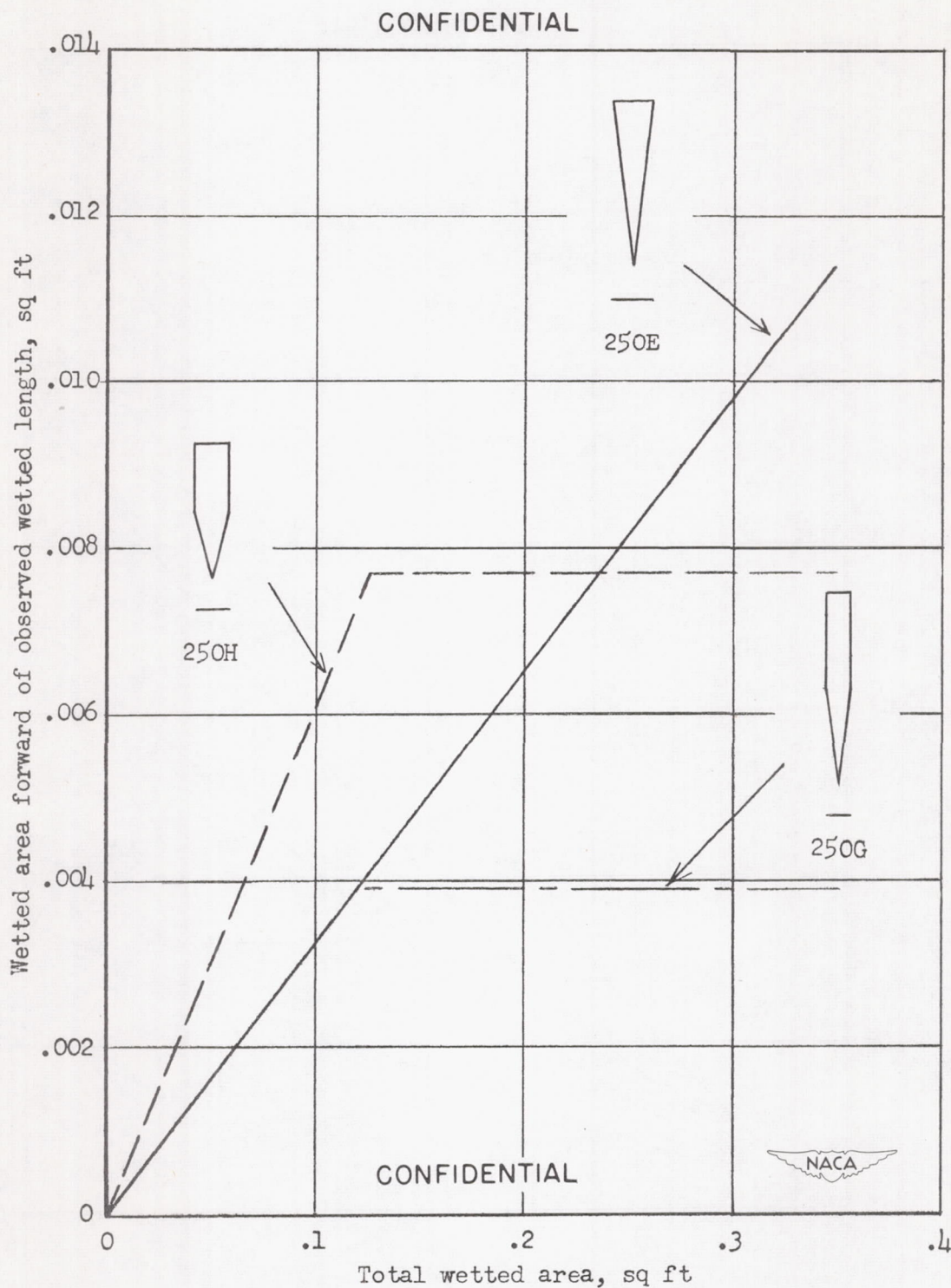


Figure 15.- Wetted area forward of the observed wetted length for models 250E, 250G, and 250H.

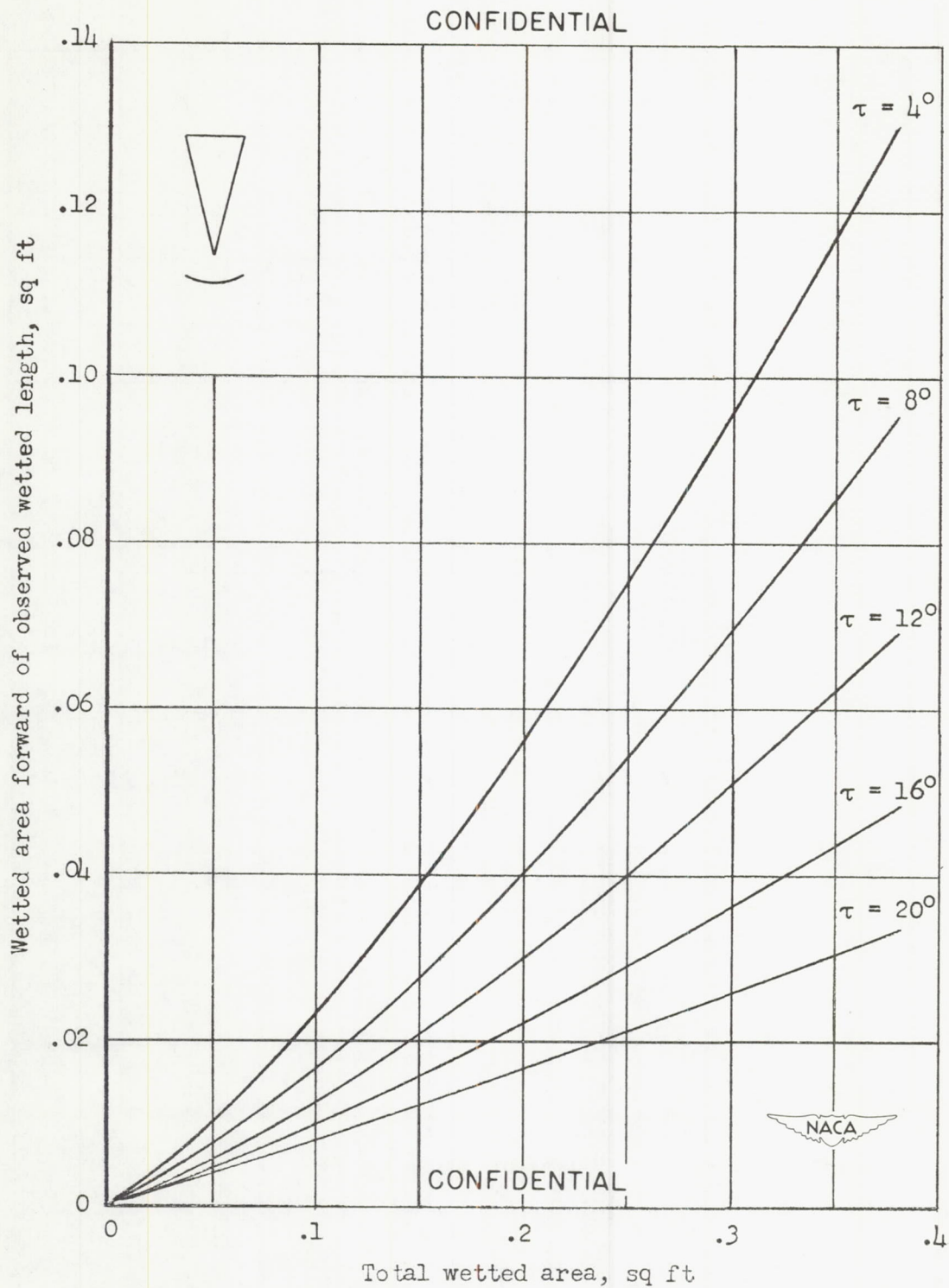
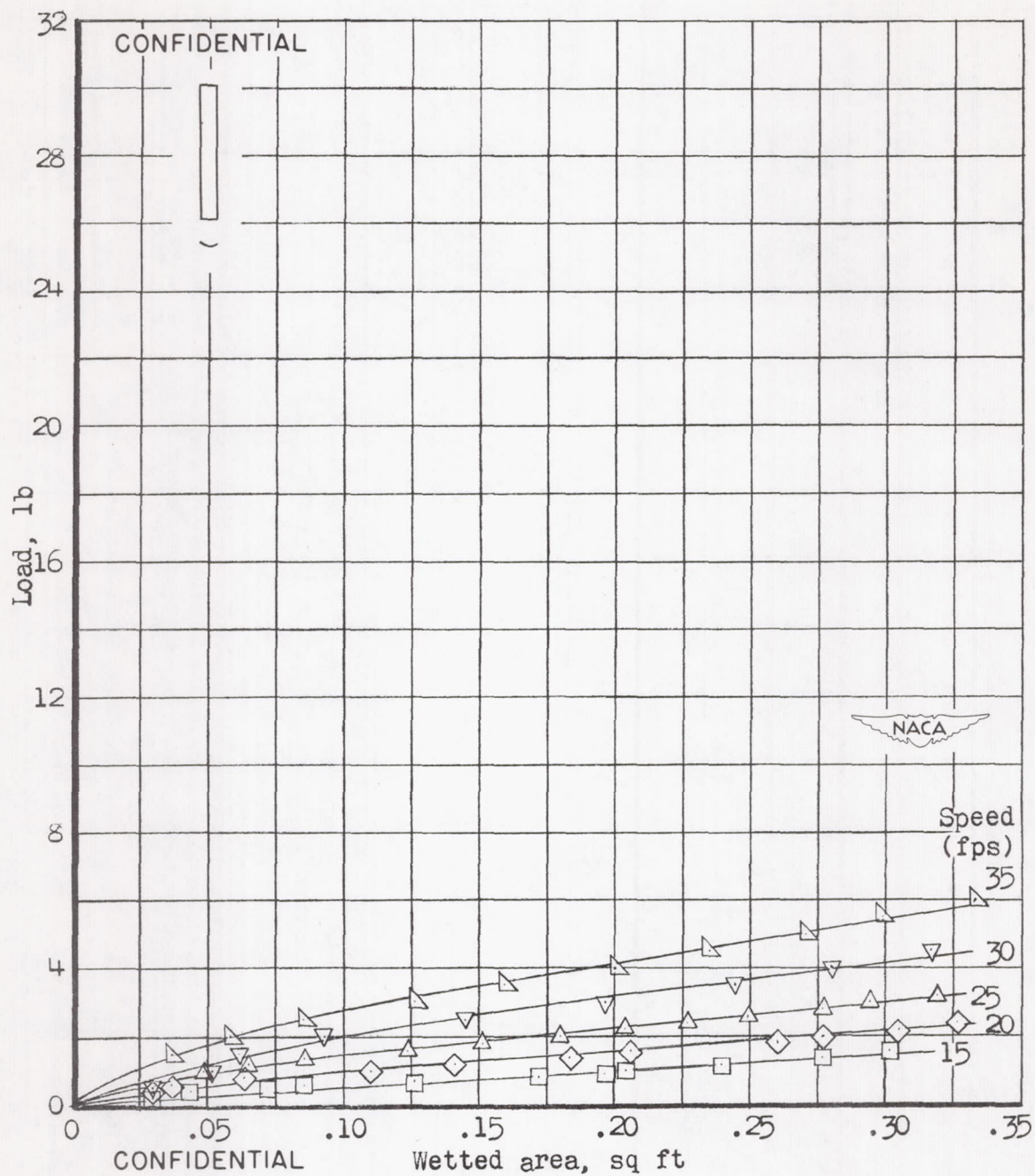
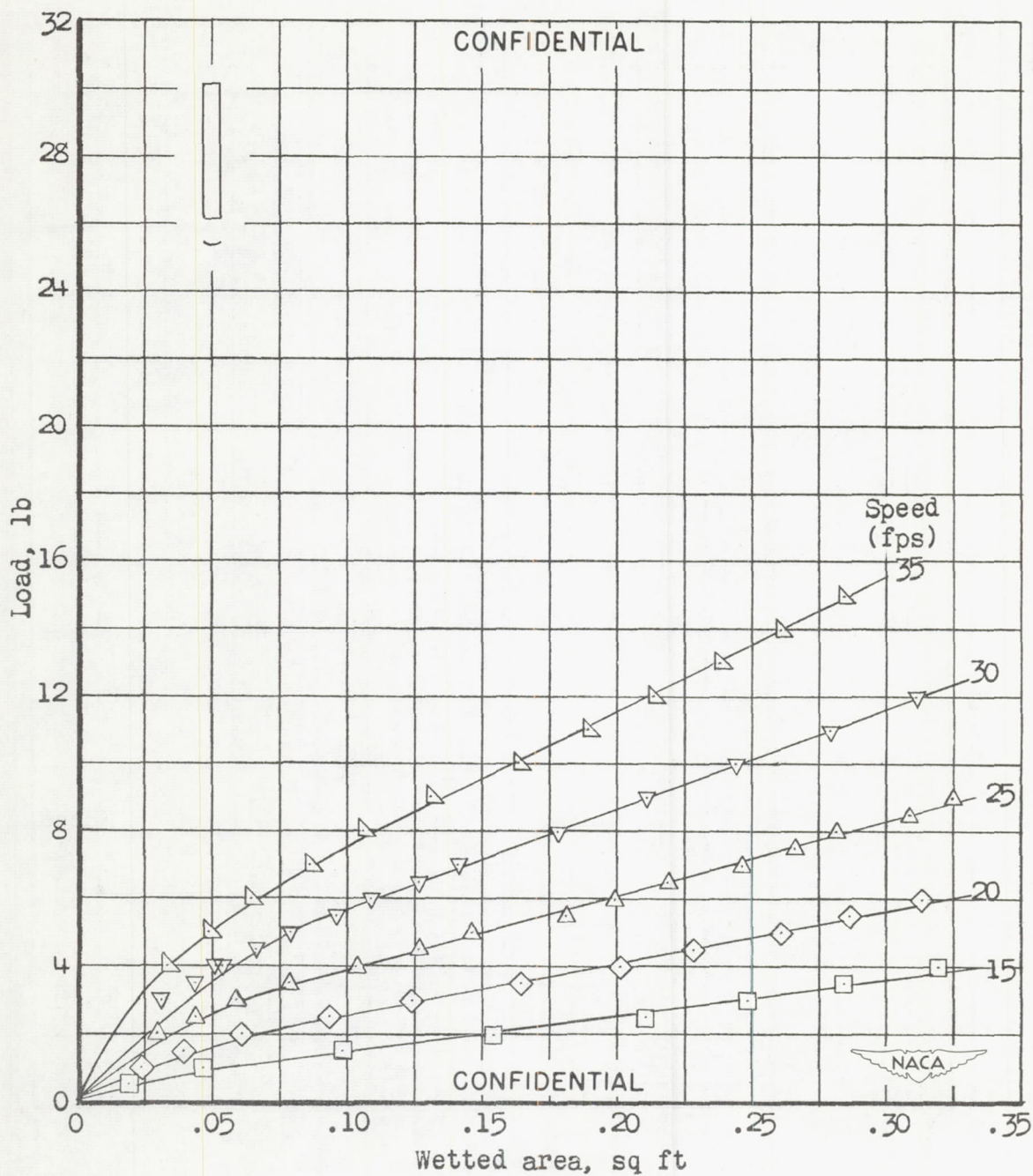


Figure 16.- Wetted area forward of the observed wetted length for model 25OF.



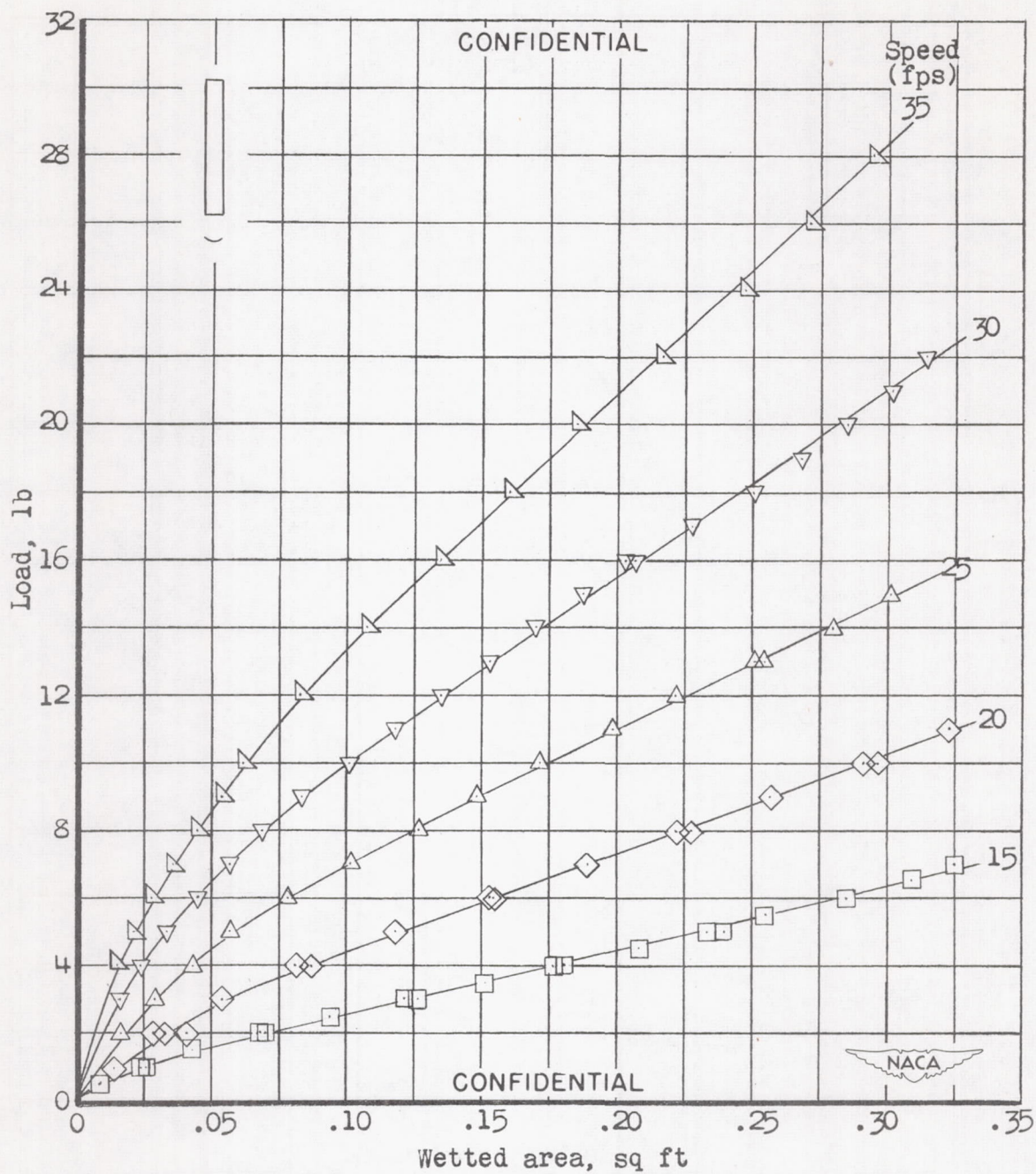
(a) $\tau = 40^\circ$.

Figure 17. Variation of load with wetted area. Model 250C.



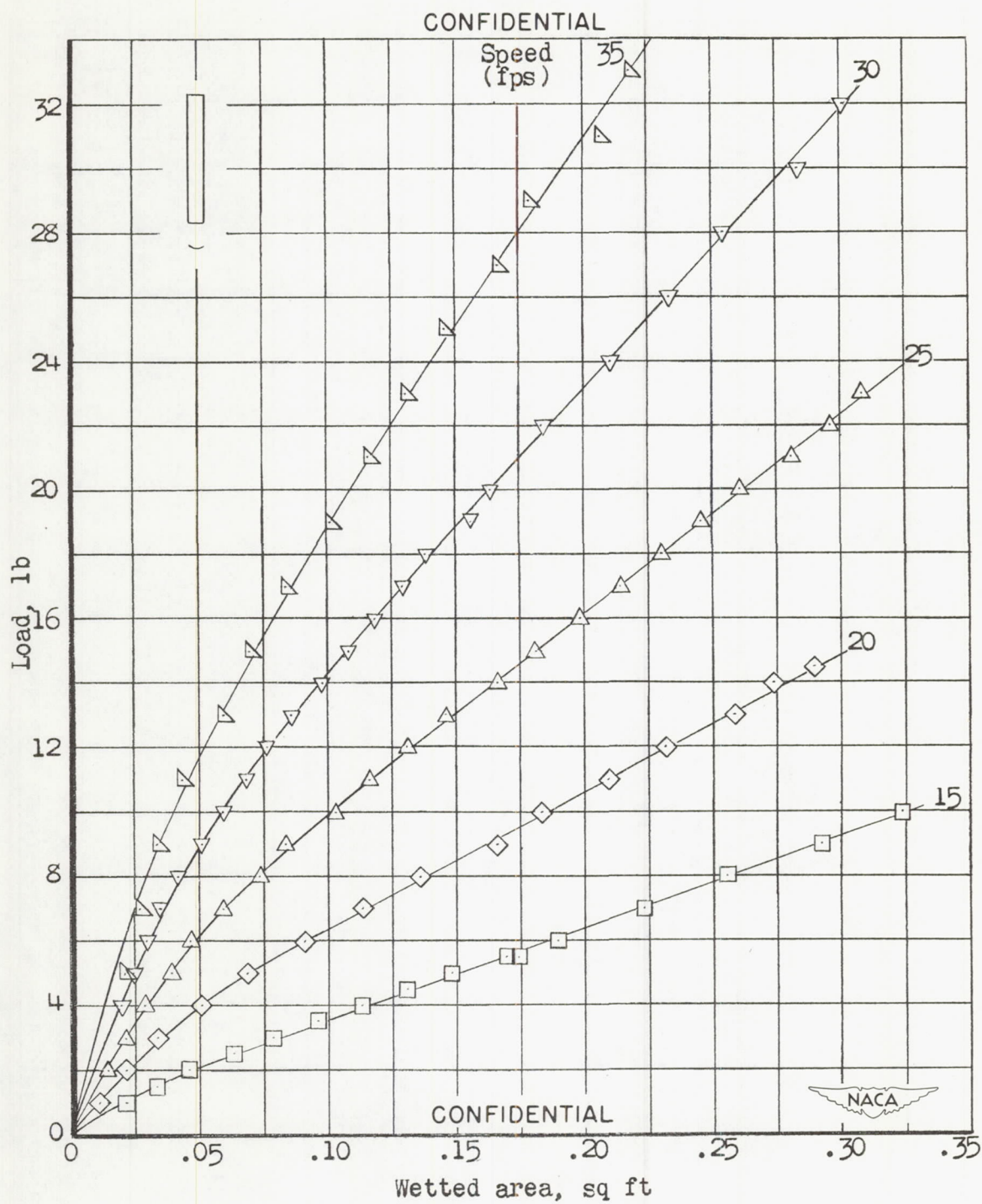
(b) $\tau = 8^\circ$.

Figure 17.- Continued.



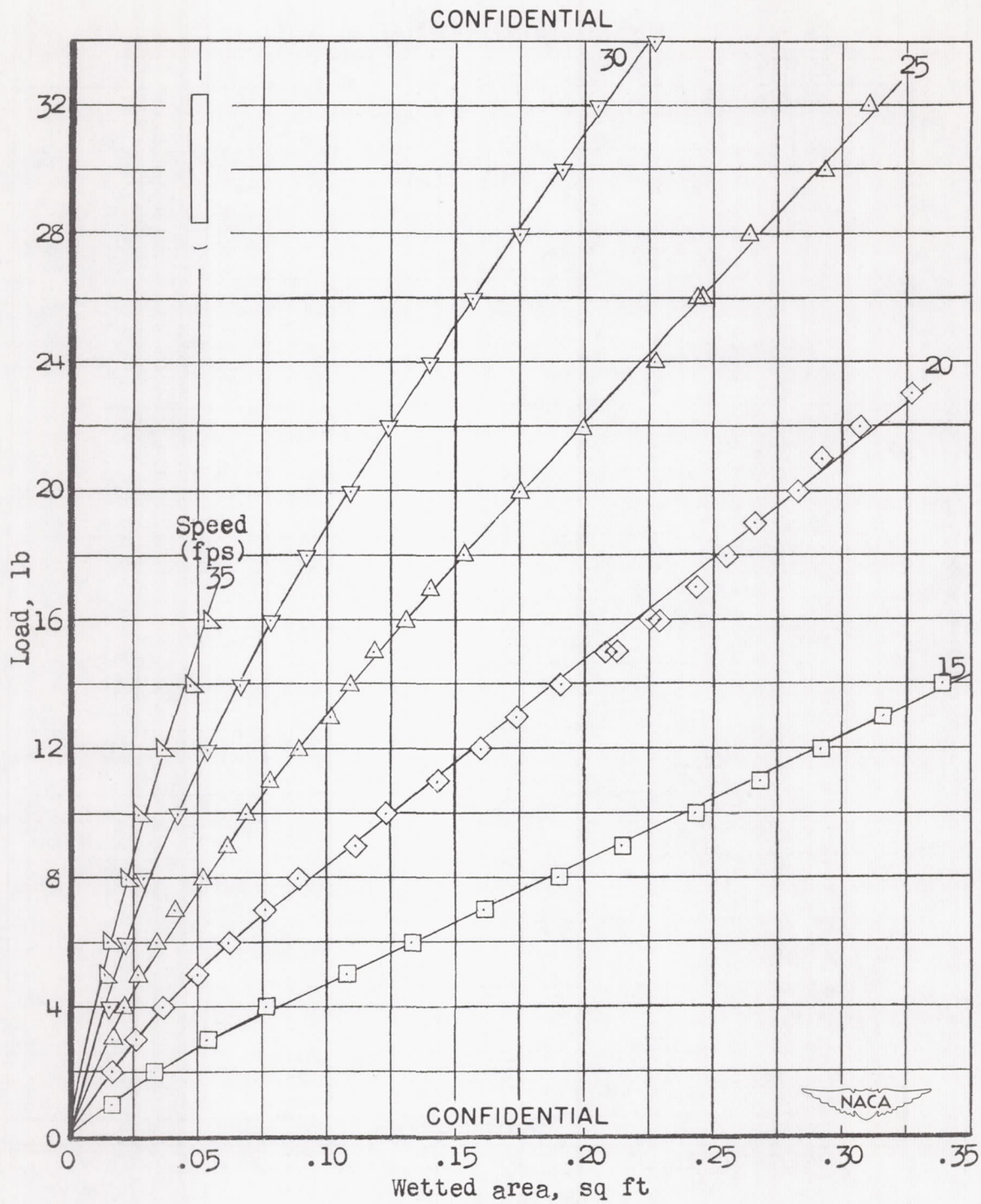
(c) $\tau = 12^\circ$.

Figure 17. Continued.



(d) $\tau = 16^\circ$.

Figure 17.- Continued.



(e) $\tau = 20^\circ$.

Figure 17. Concluded.

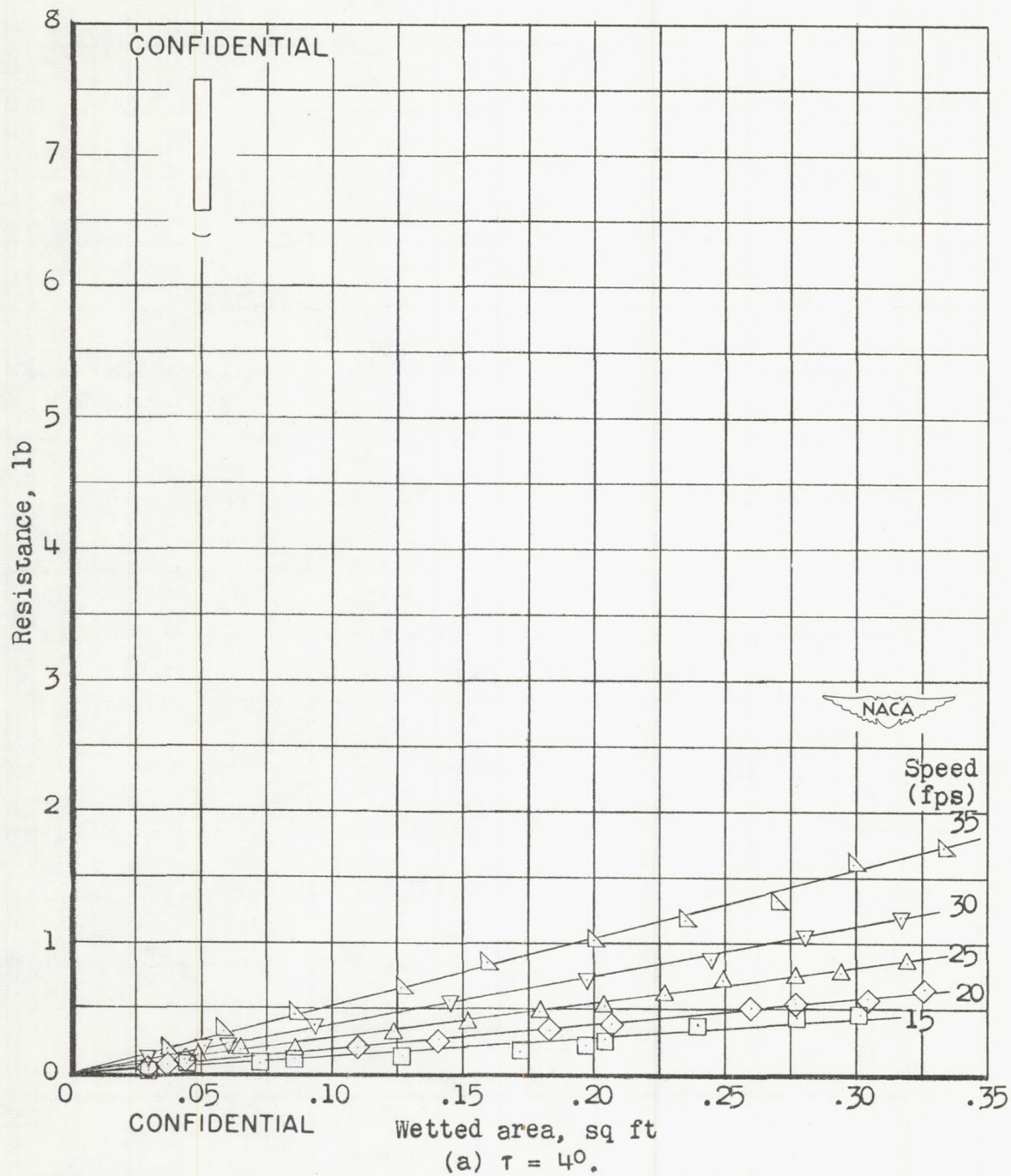
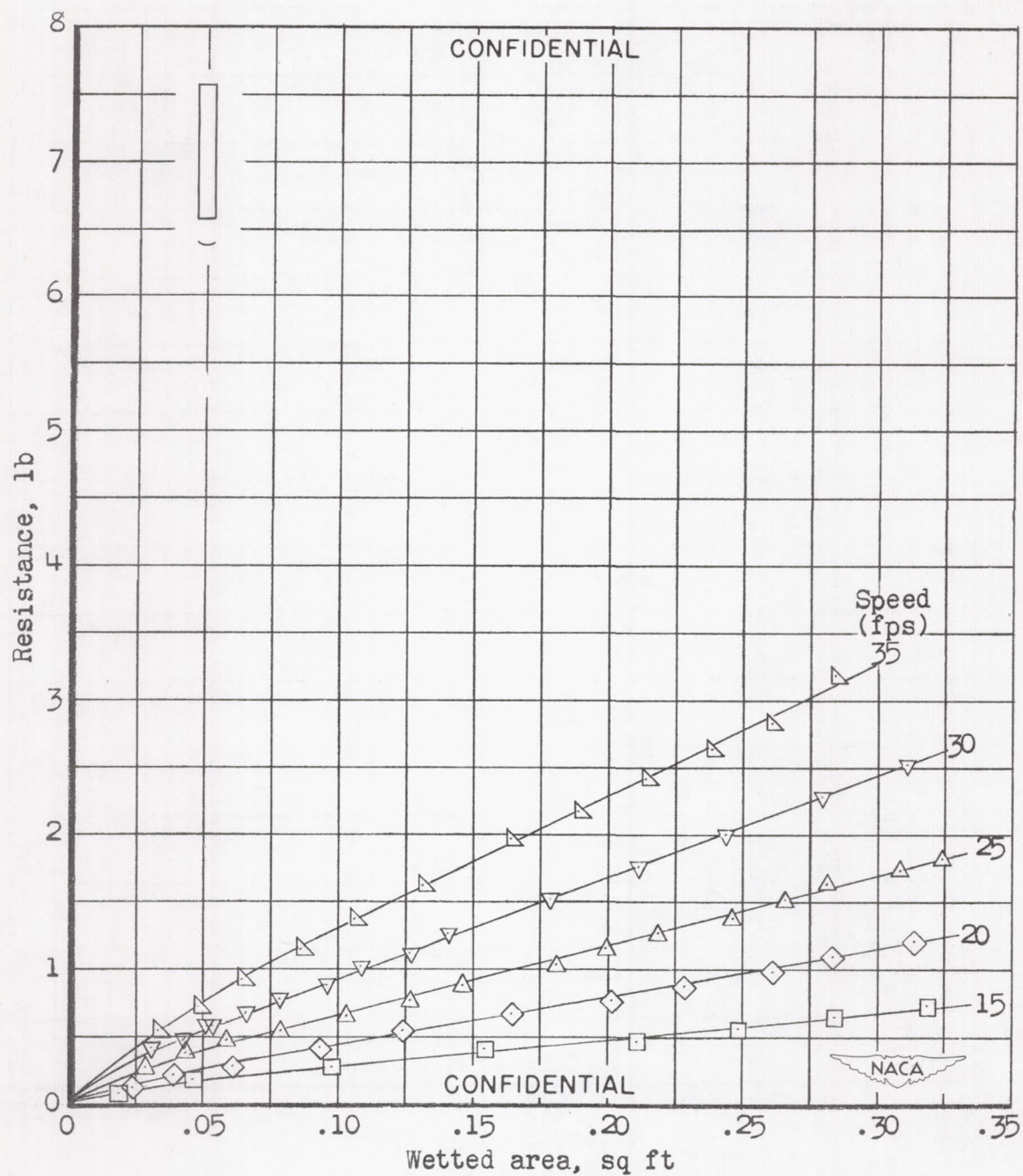
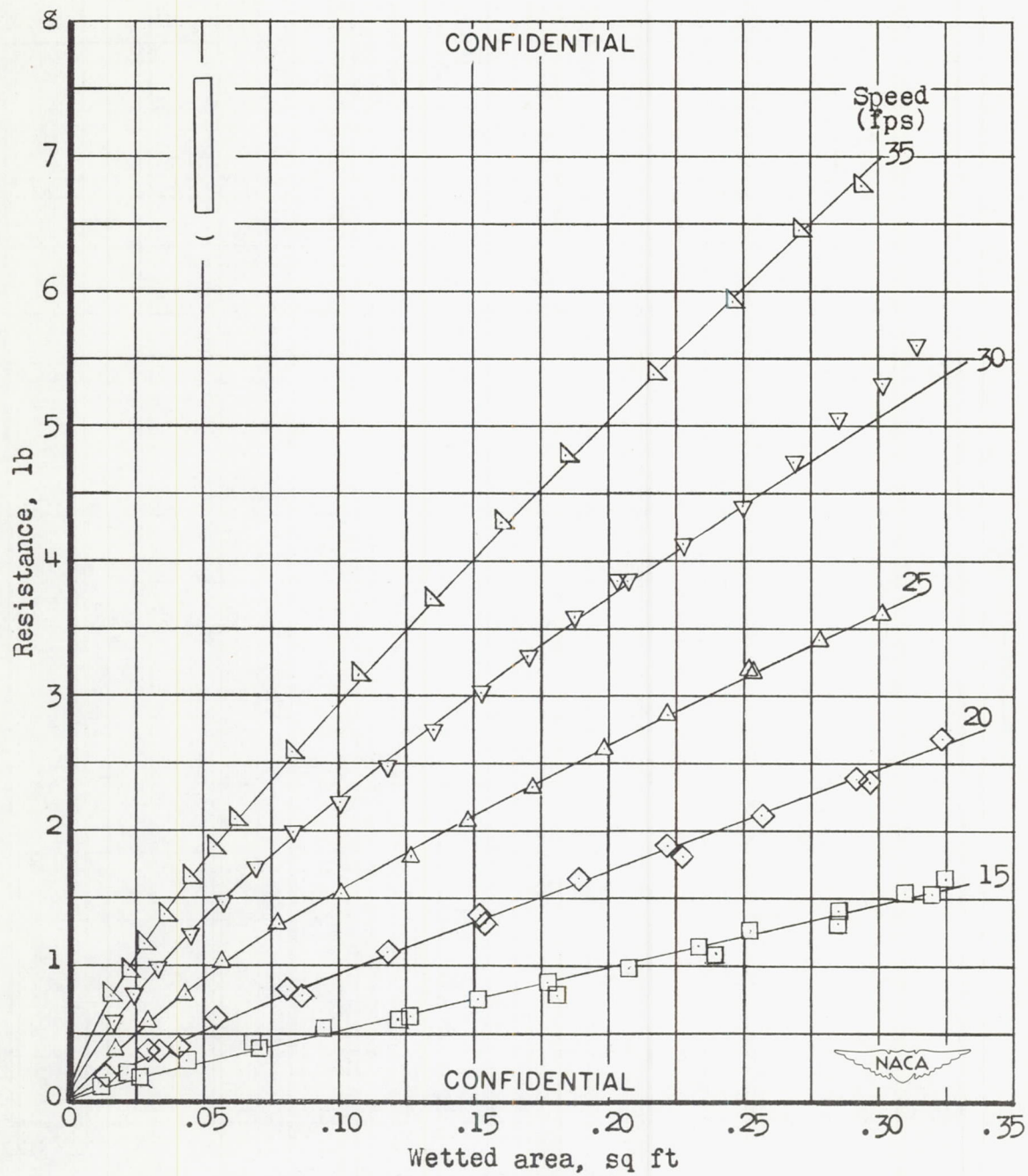


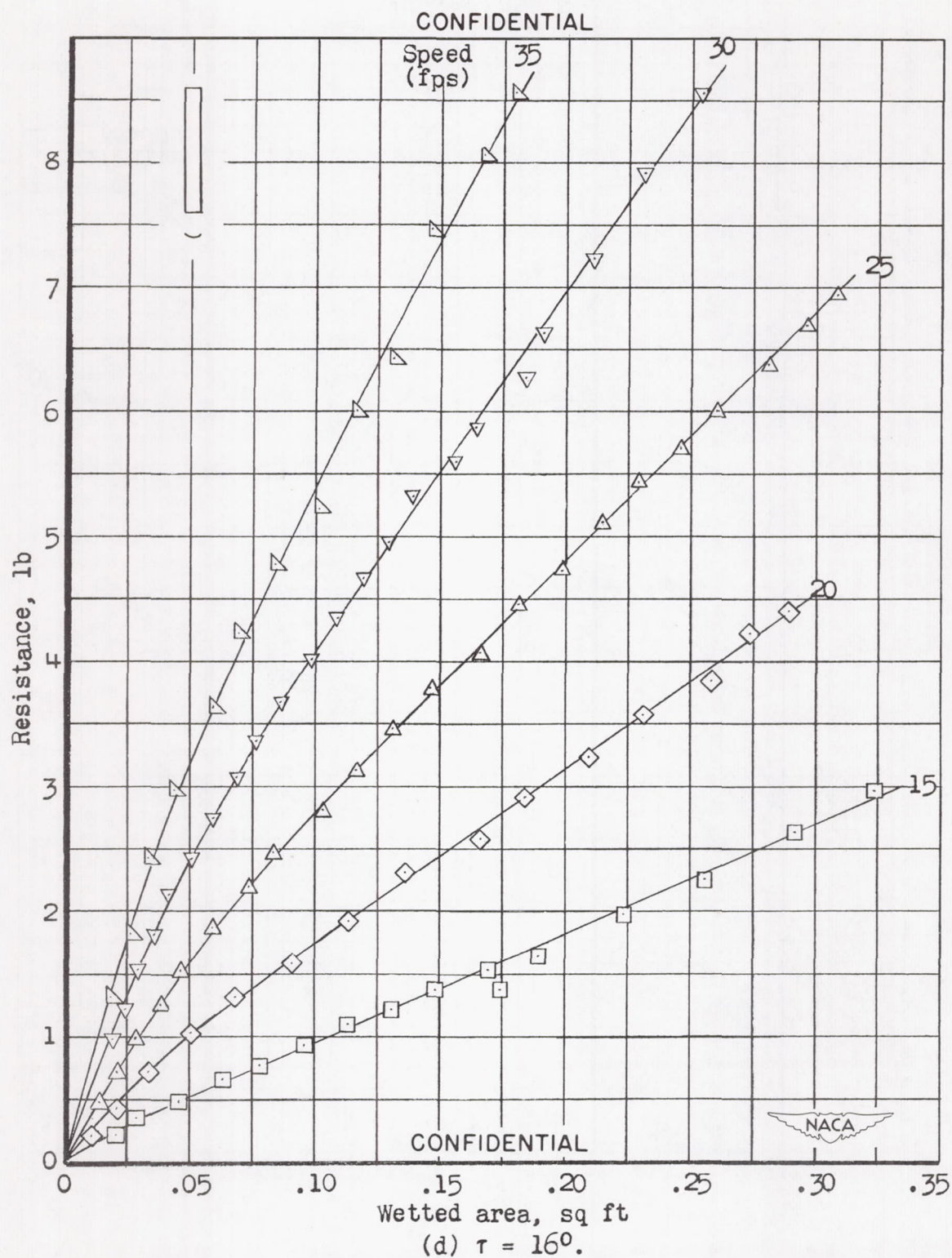
Figure 18.- Variation of resistance with wetted area. Model 250C.



(b) $\tau = 80^\circ$.
Figure 18.- Continued.



(c) $\tau = 12^\circ$.
Figure 18.- Continued.



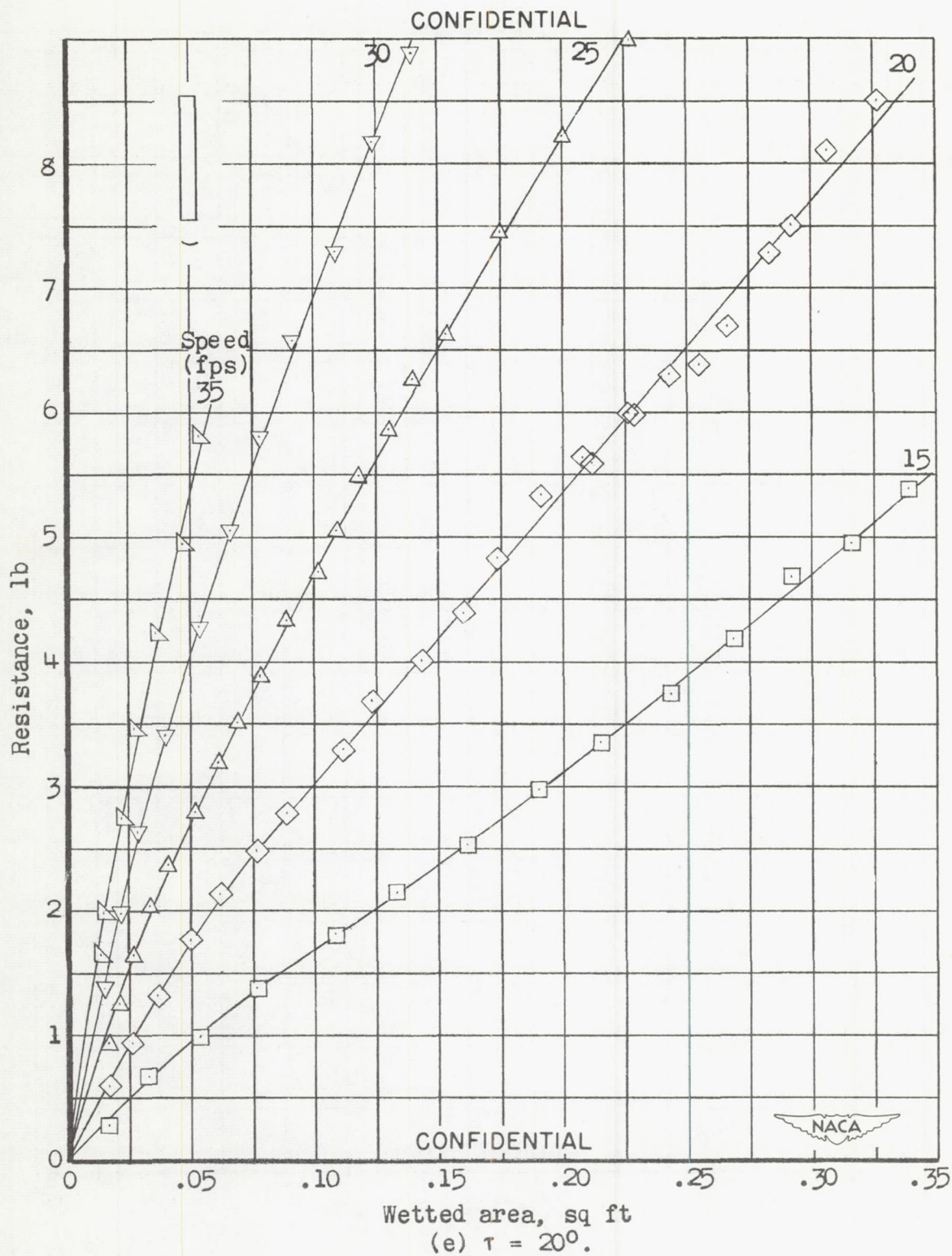


Figure 18.- Concluded.

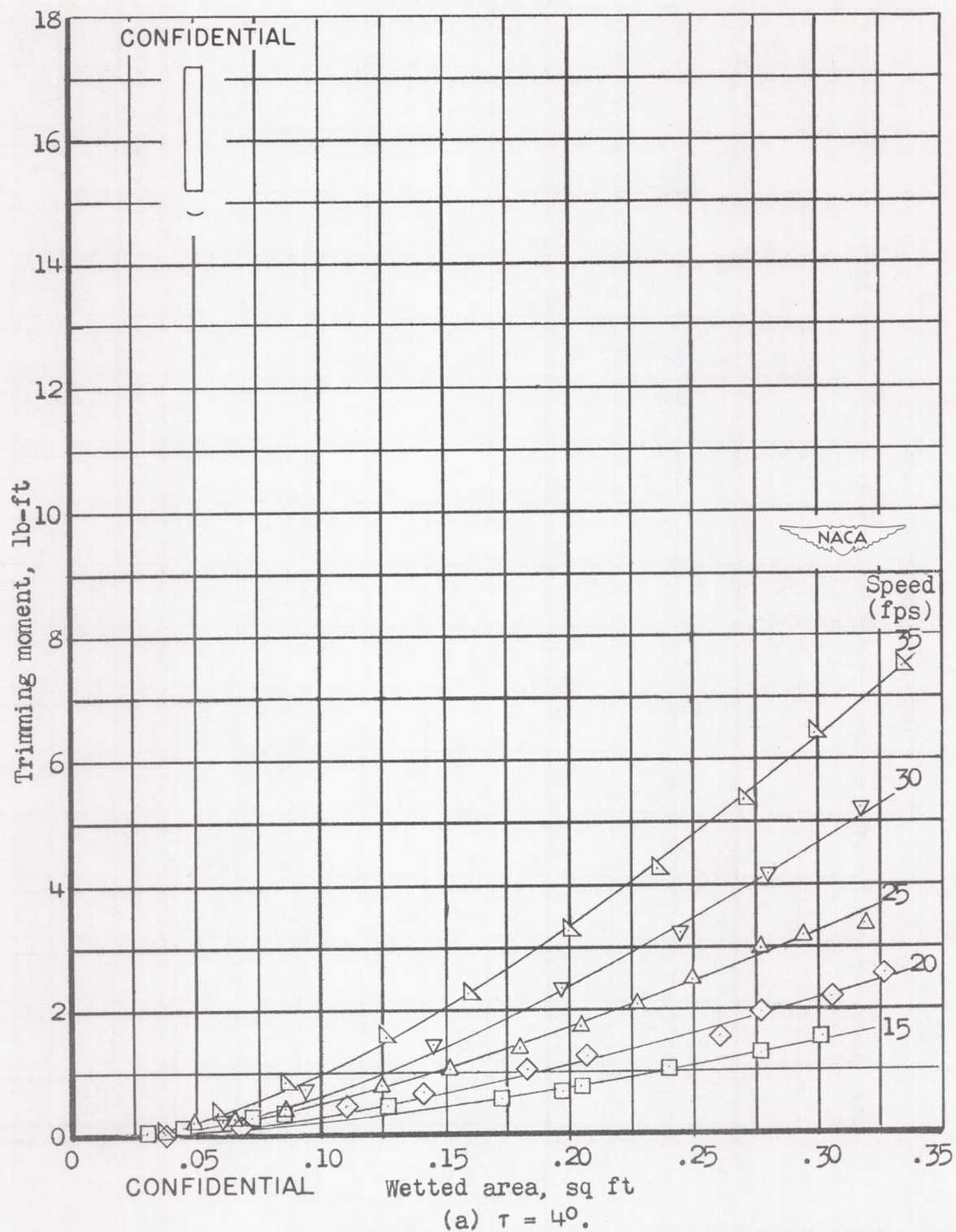
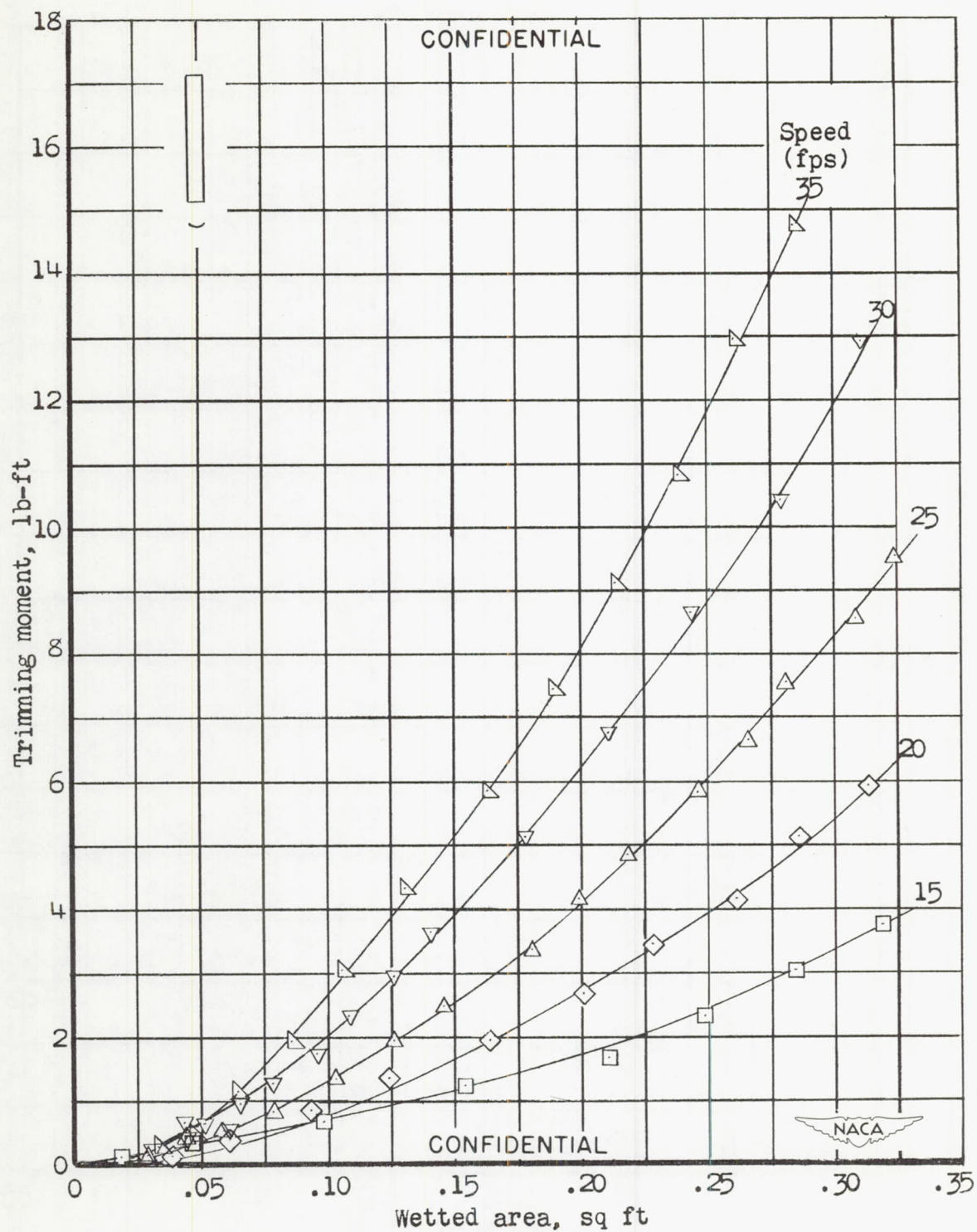


Figure 19.- Variation of moment with wetted area. Model 250C.



(b) $\tau = 8^\circ$.
Figure 19.- Continued.

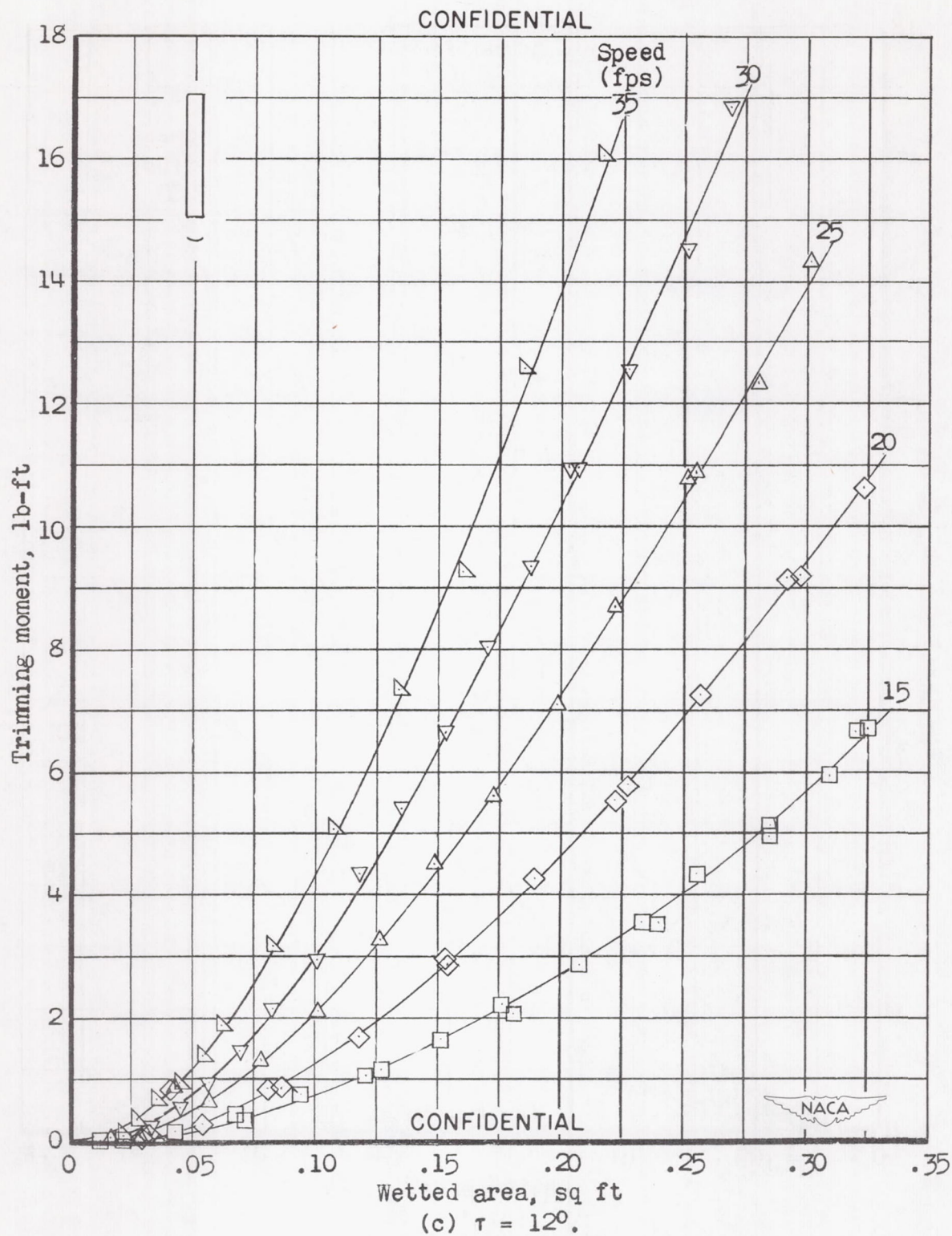


Figure 19.- Continued.

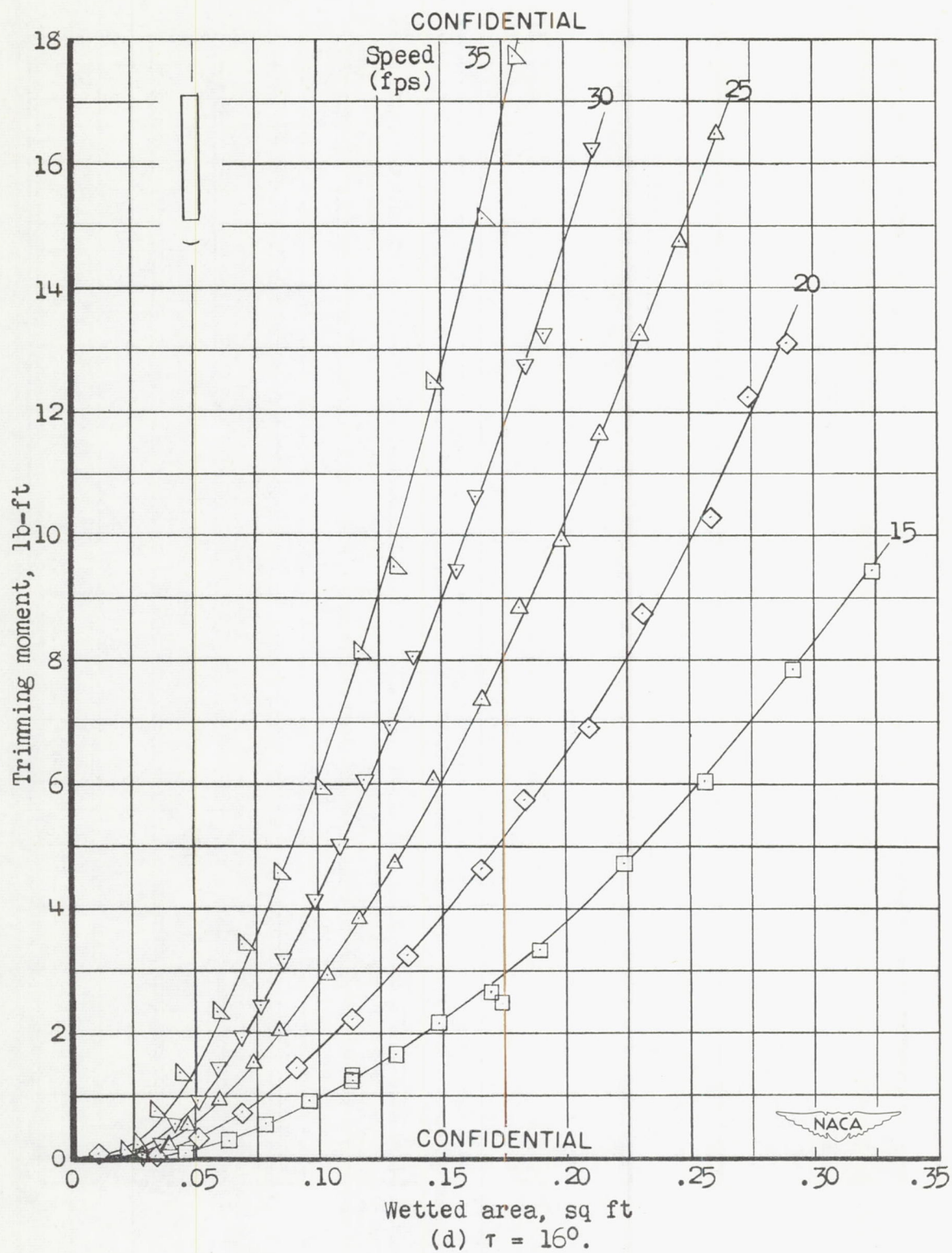
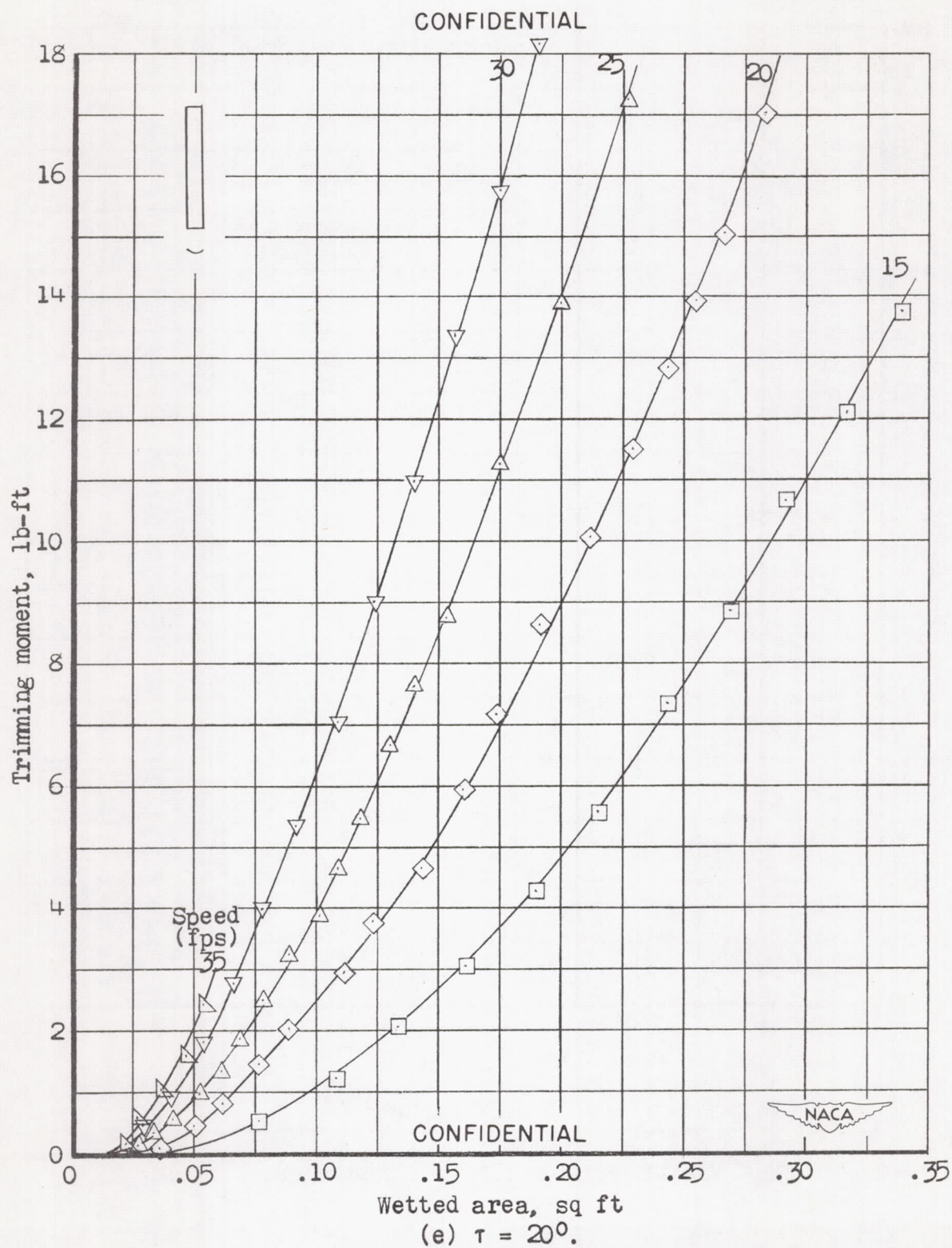
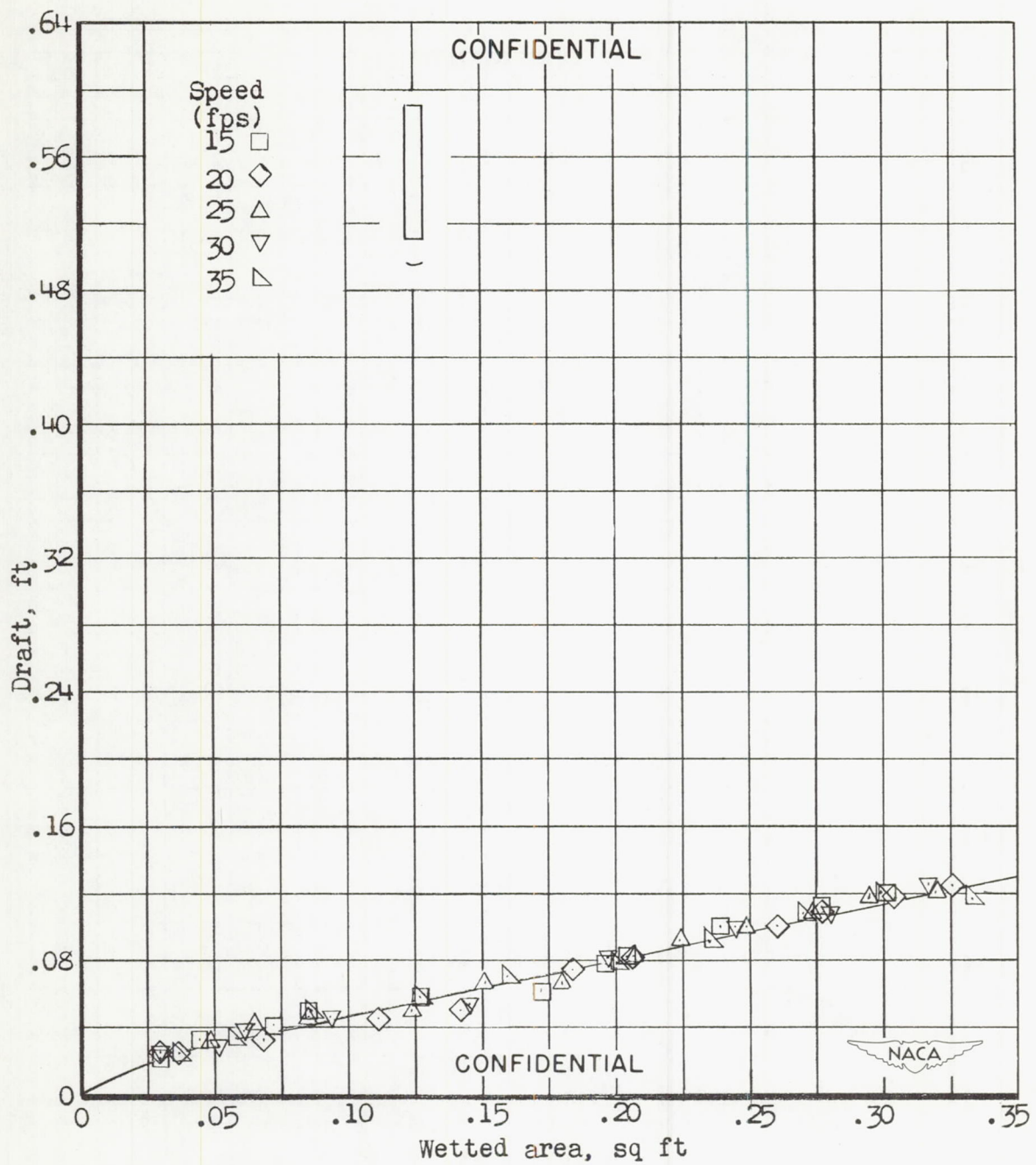


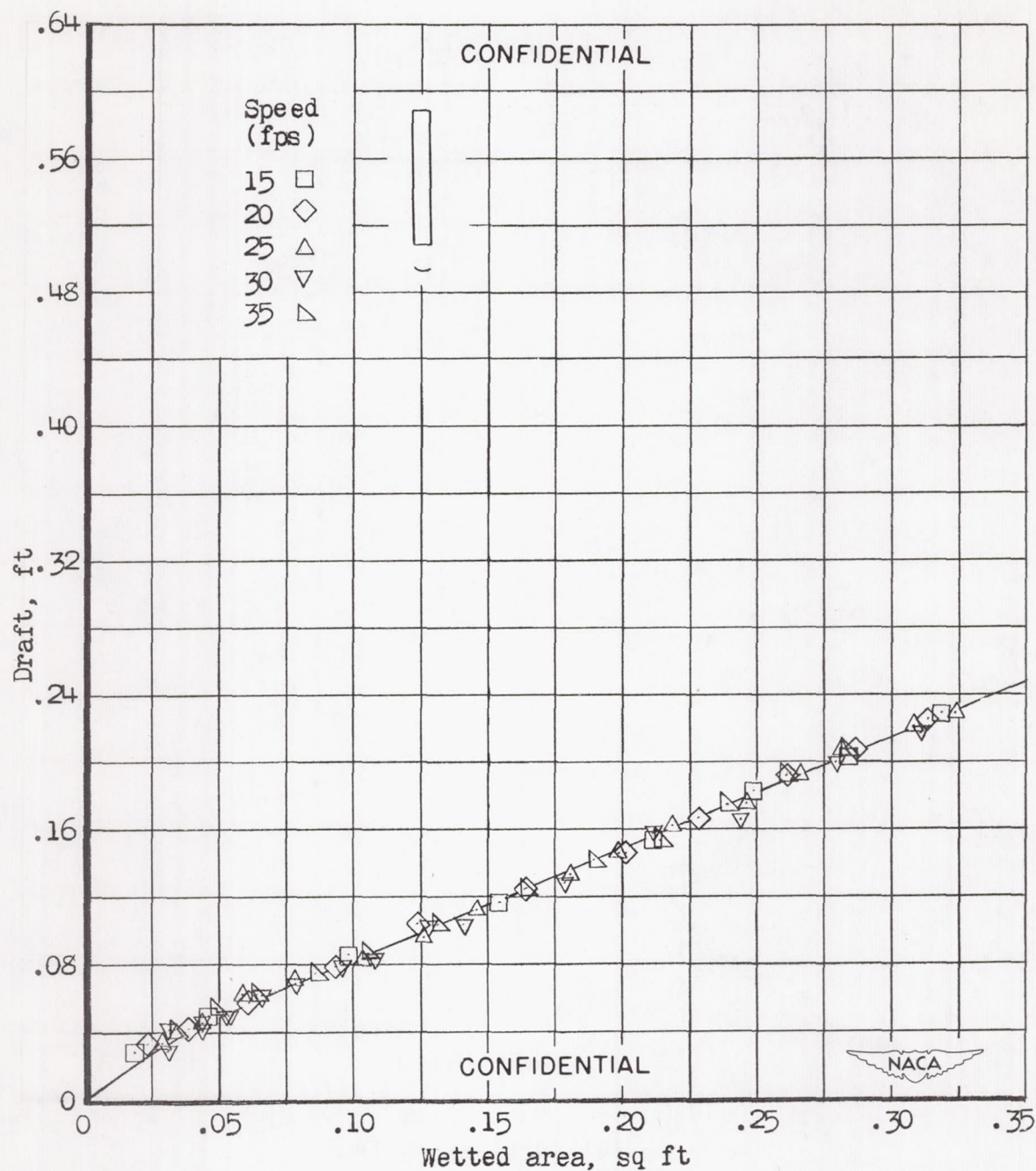
Figure 19.- Continued.





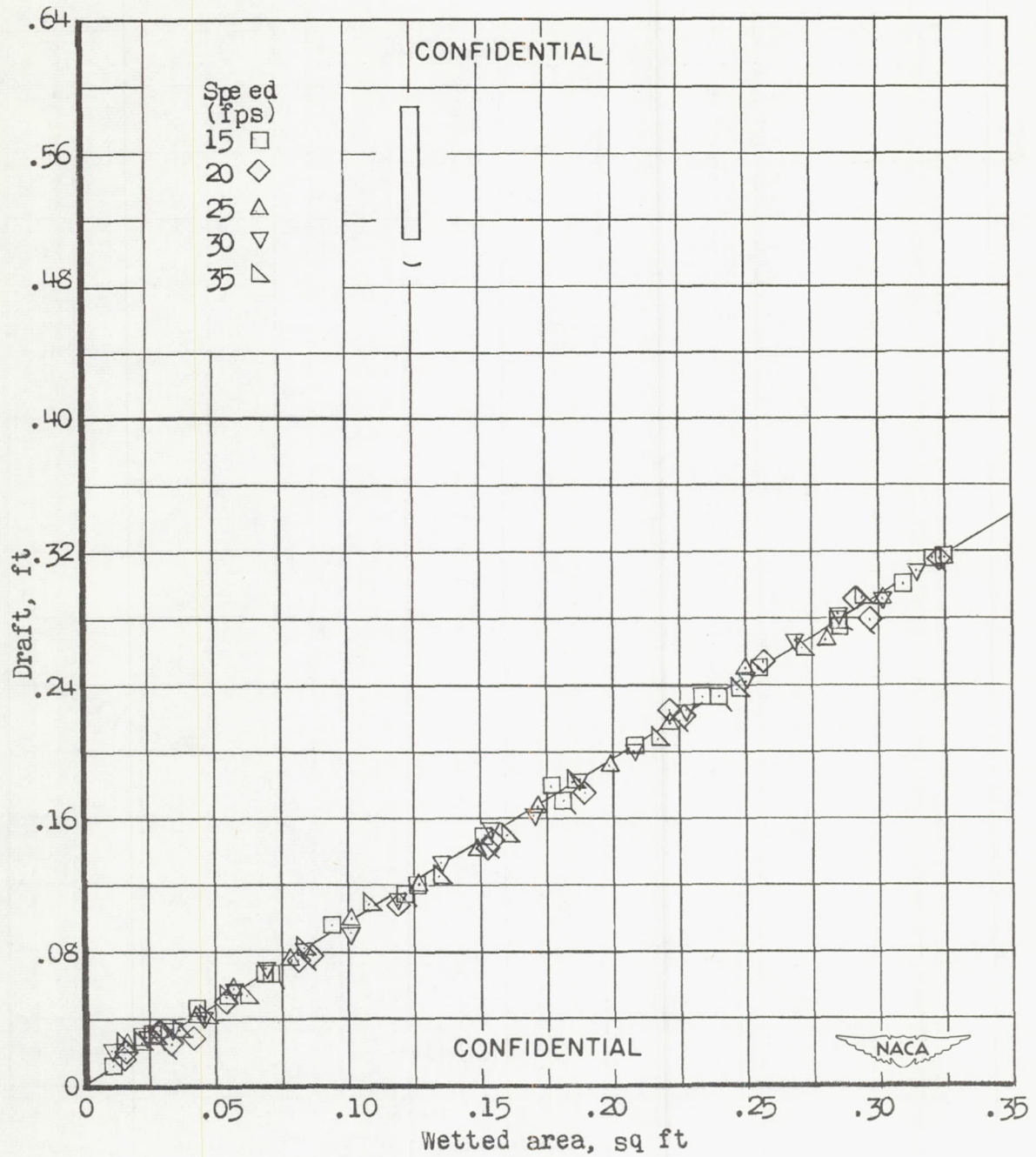
(a) $\tau = 4^\circ$.

Figure 20.- Variation of draft with wetted area. Model 250C.



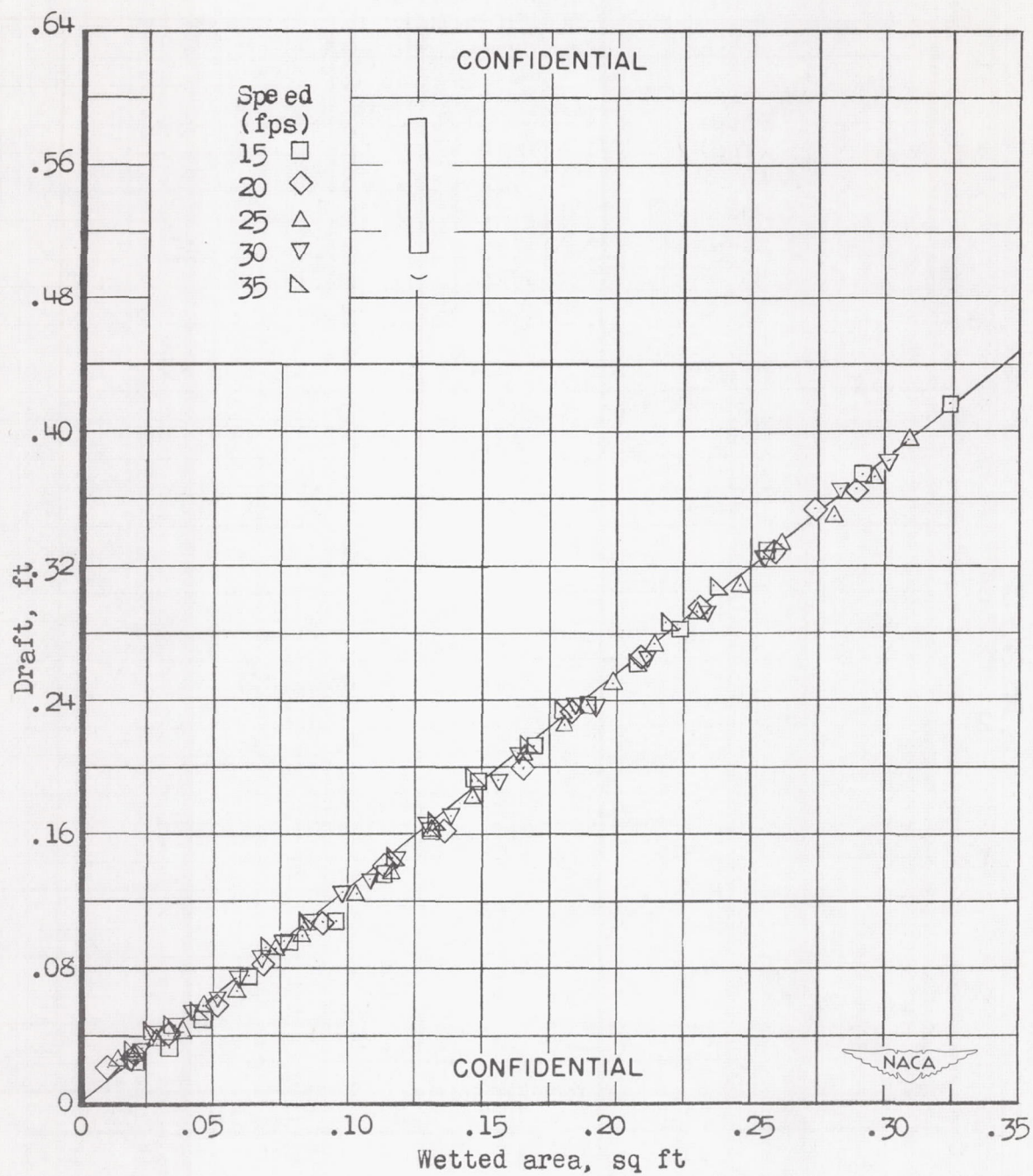
(b) $\tau = 8^\circ$.

Figure 20.- Continued.



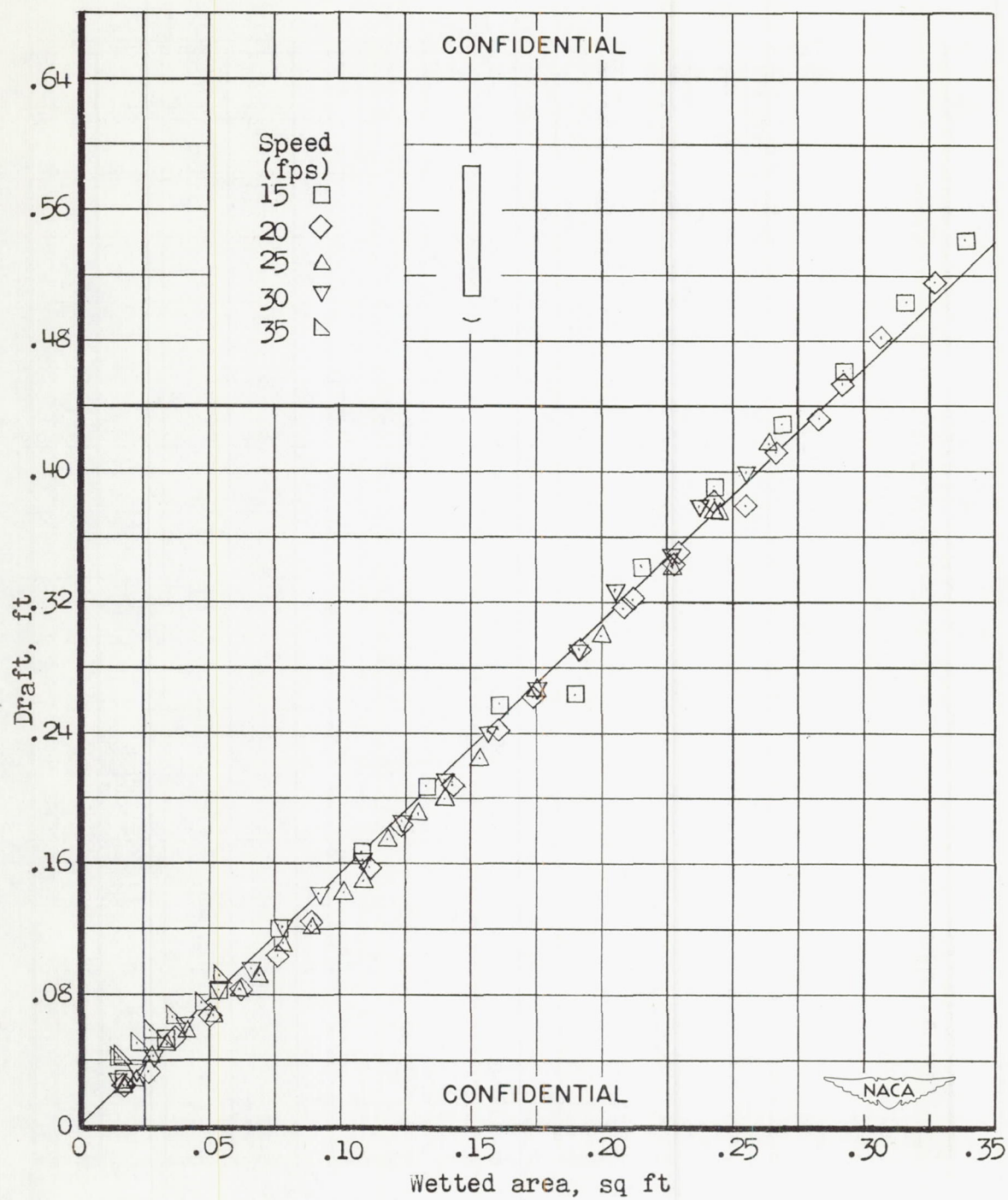
(c) $\tau = 12^\circ$.

Figure 20.- Continued.



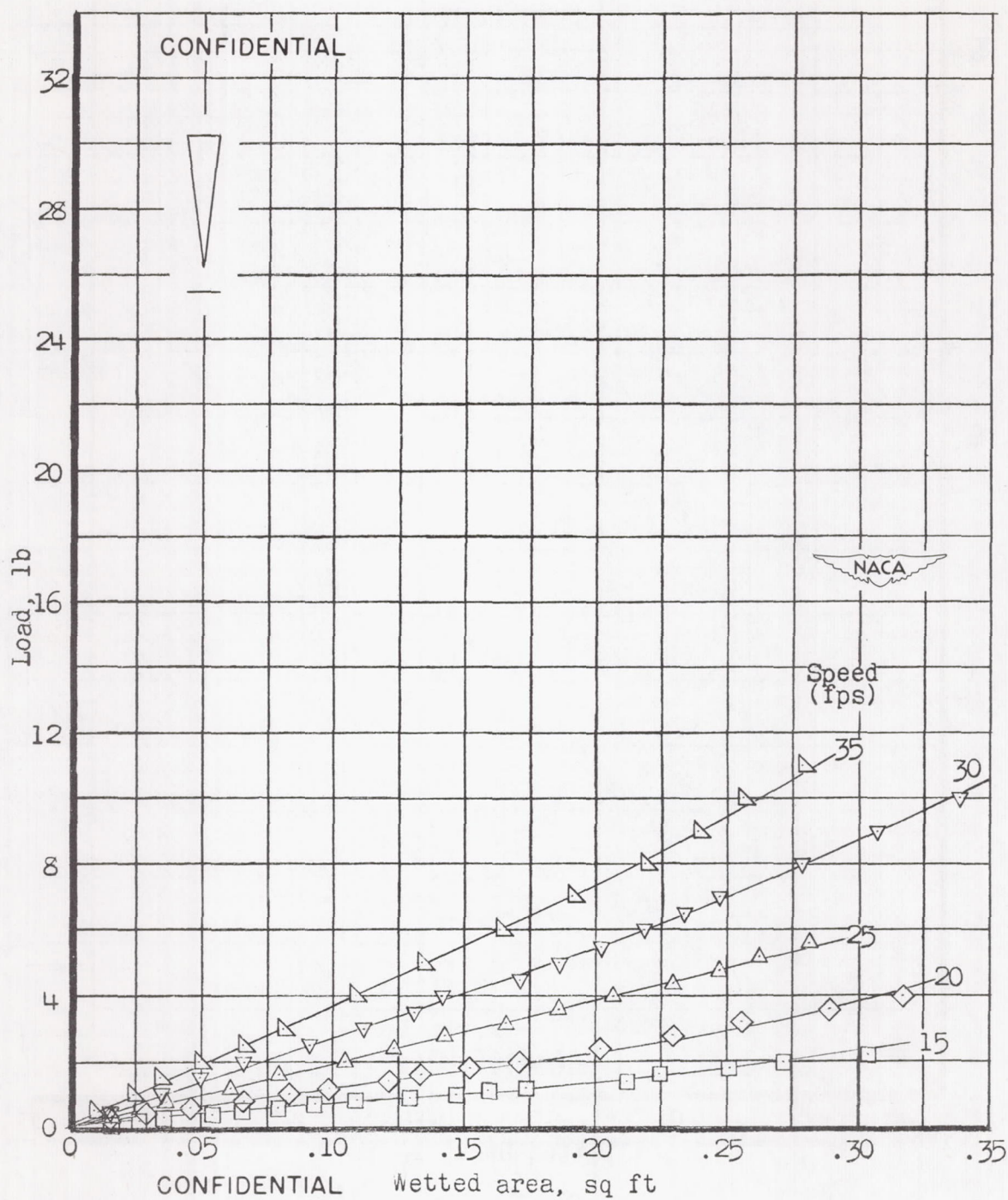
(d) $\tau = 16^\circ$.

Figure 20.- Continued.



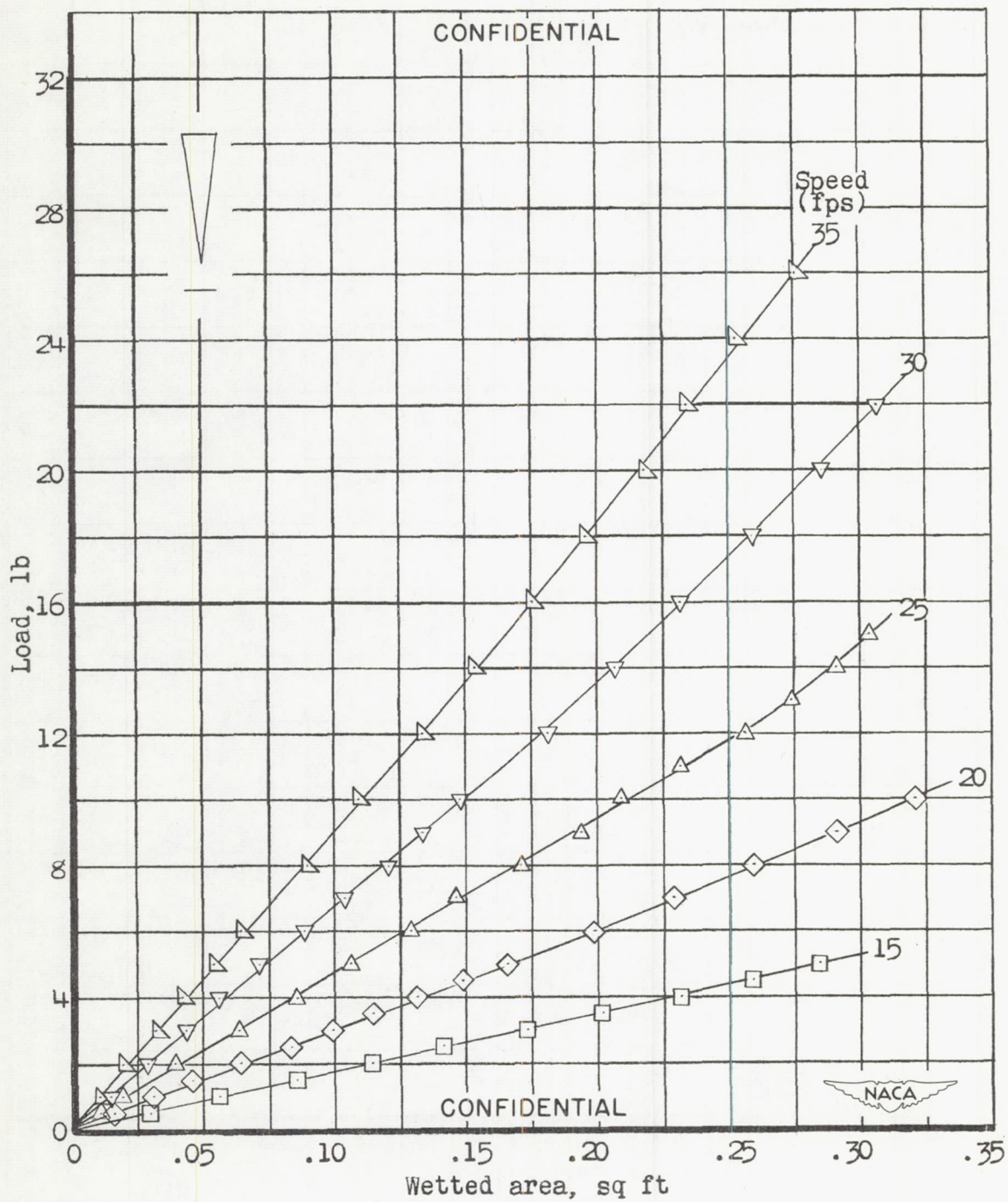
(e) $\tau = 20^\circ$.

Figure 20.- Concluded.



(a) $\tau = 4^\circ$.

Figure 21.- Variation of load with wetted area. Model 250-E.



(b) $\tau = 8^\circ$.

Figure 21.- Continued.

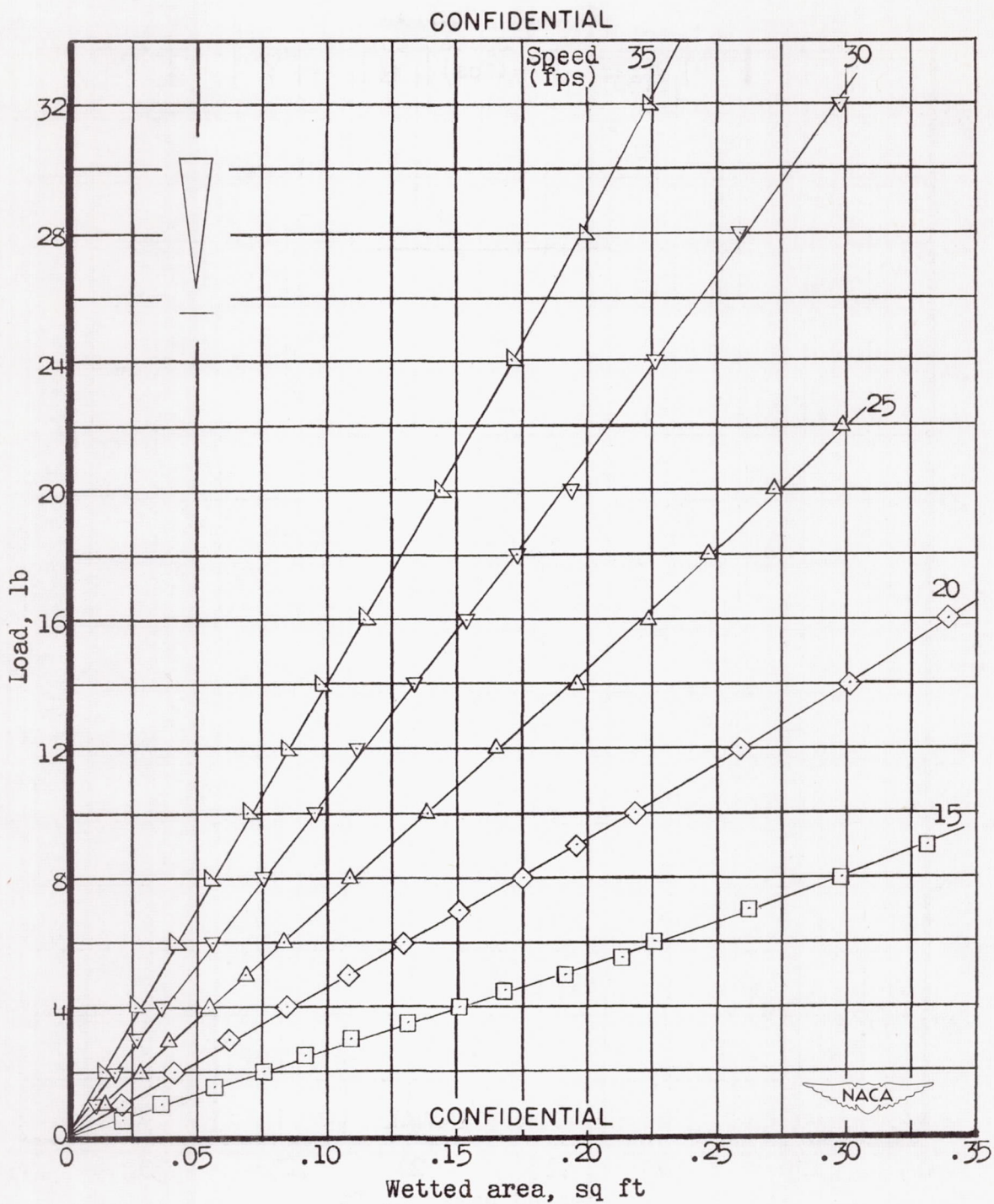
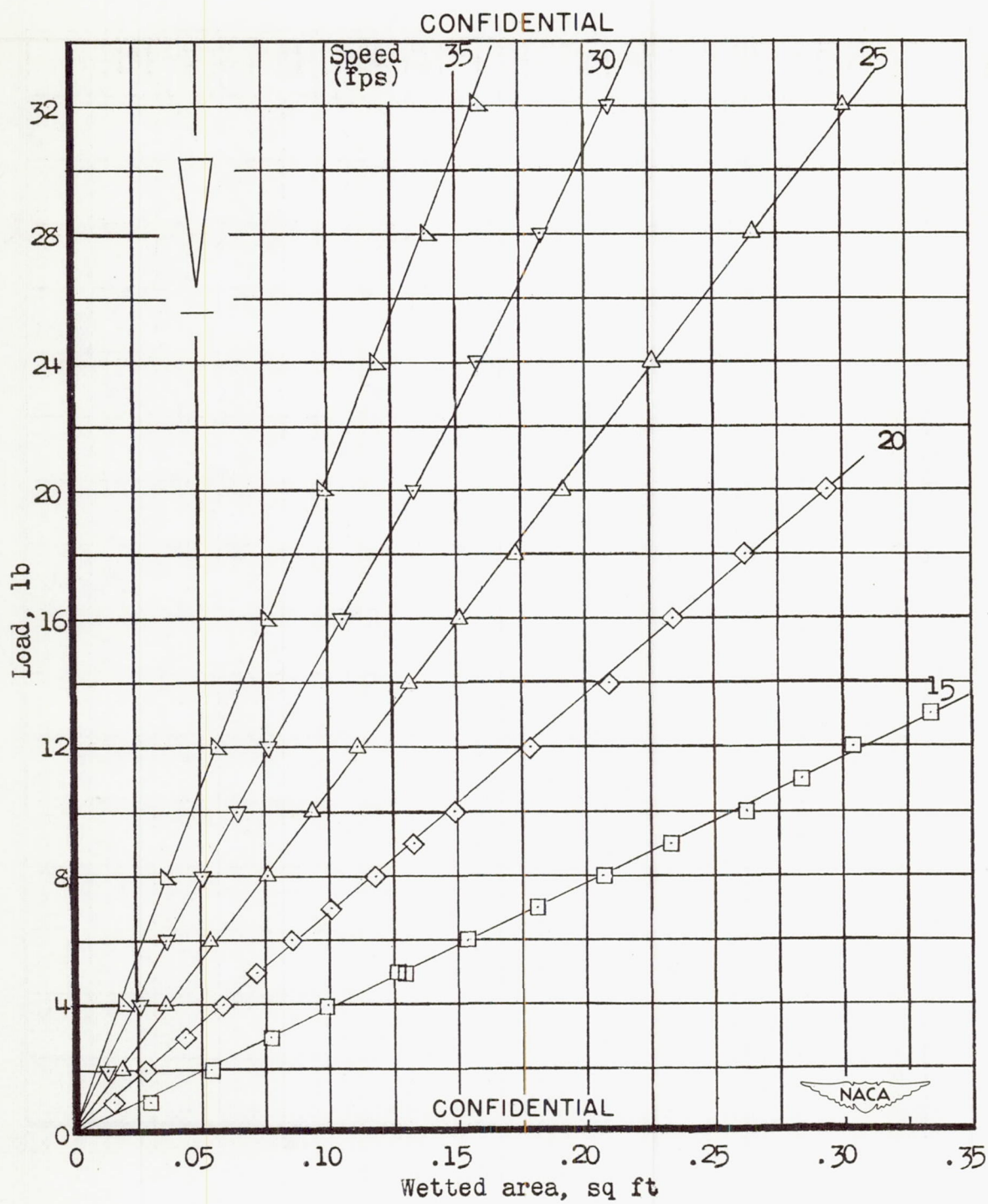
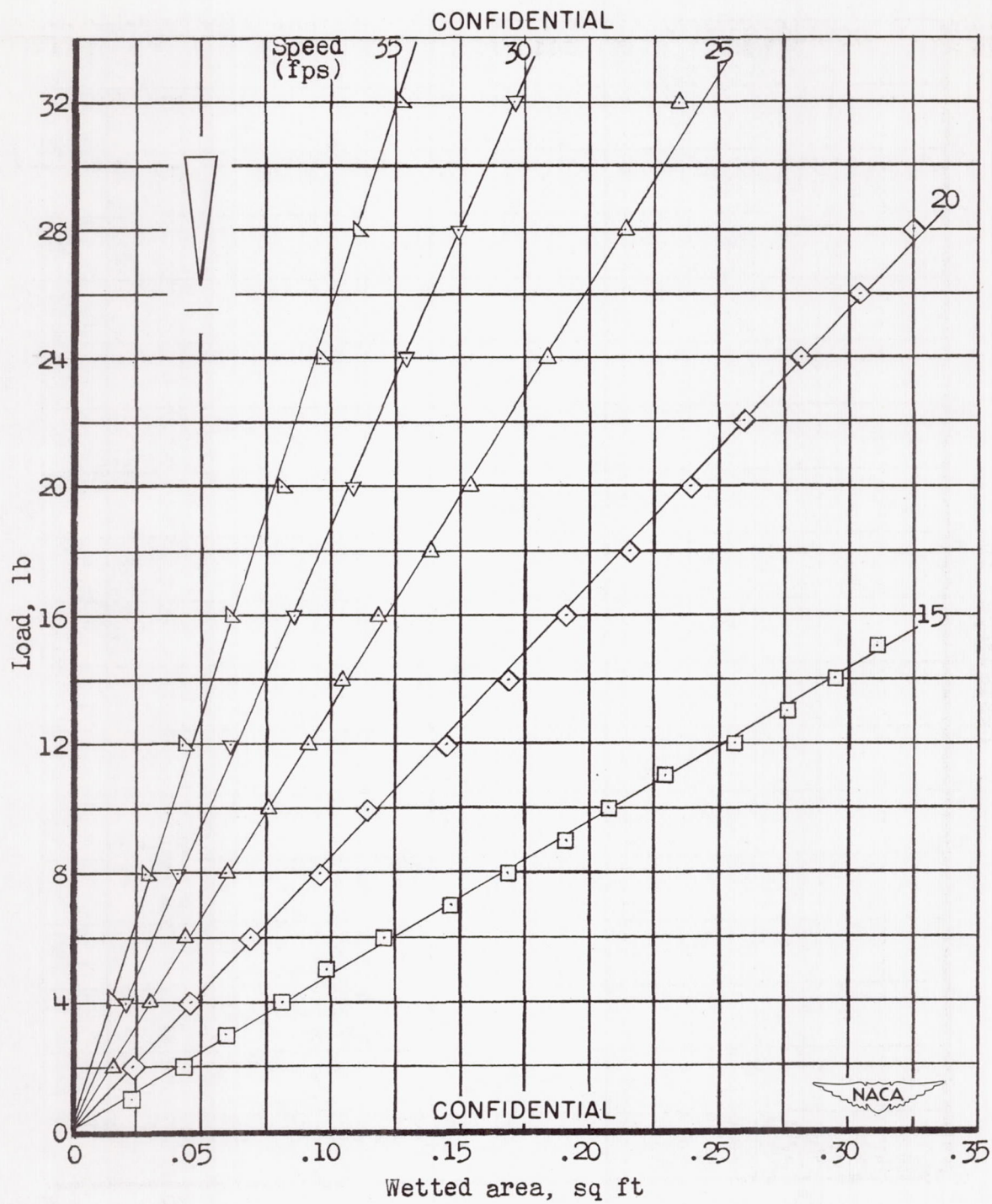


Figure 21.- Continued.



(d) $\tau = 16^\circ$.

Figure 21.- Continued.



(e) $\tau = 20^\circ$.

Figure 21.- Concluded.

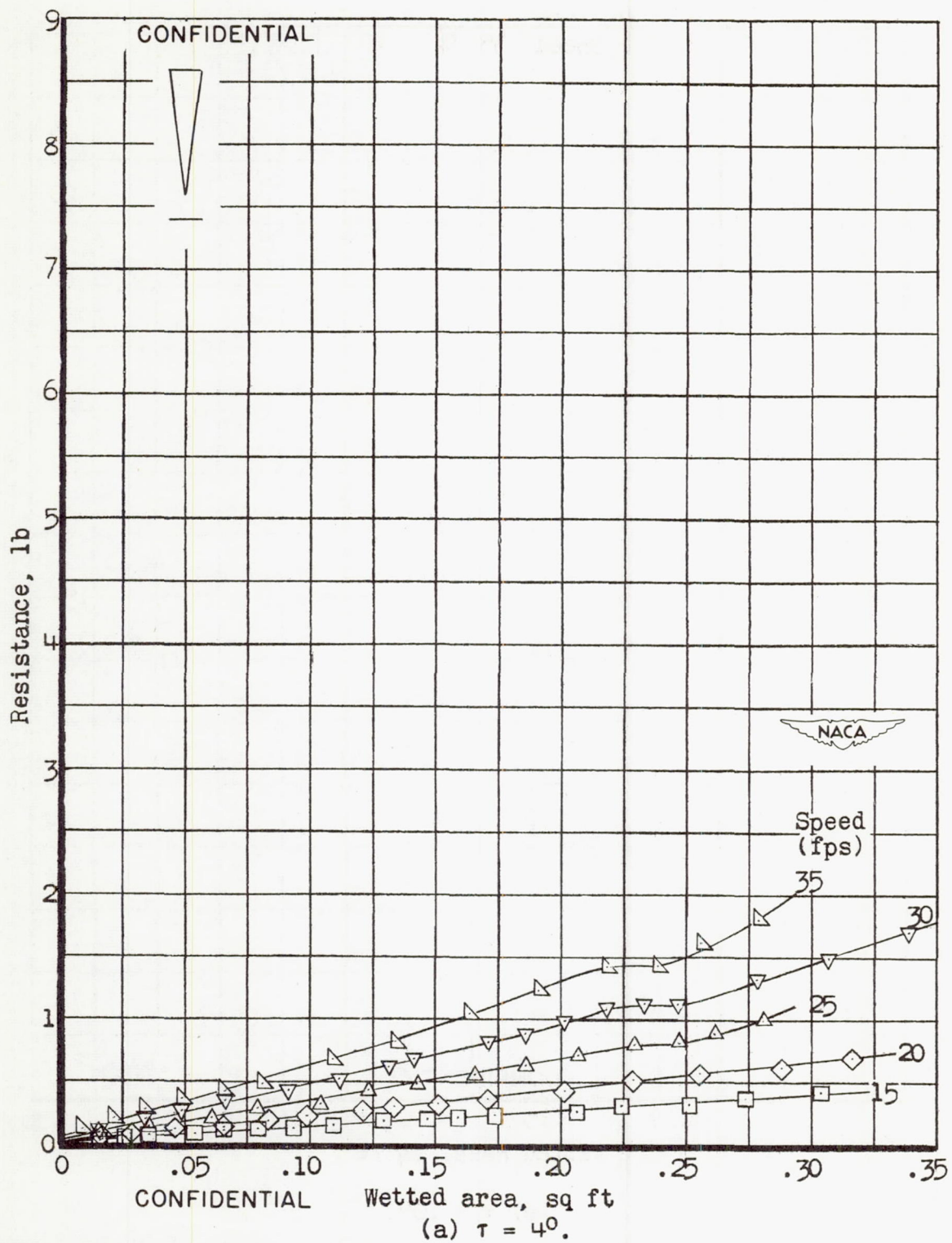
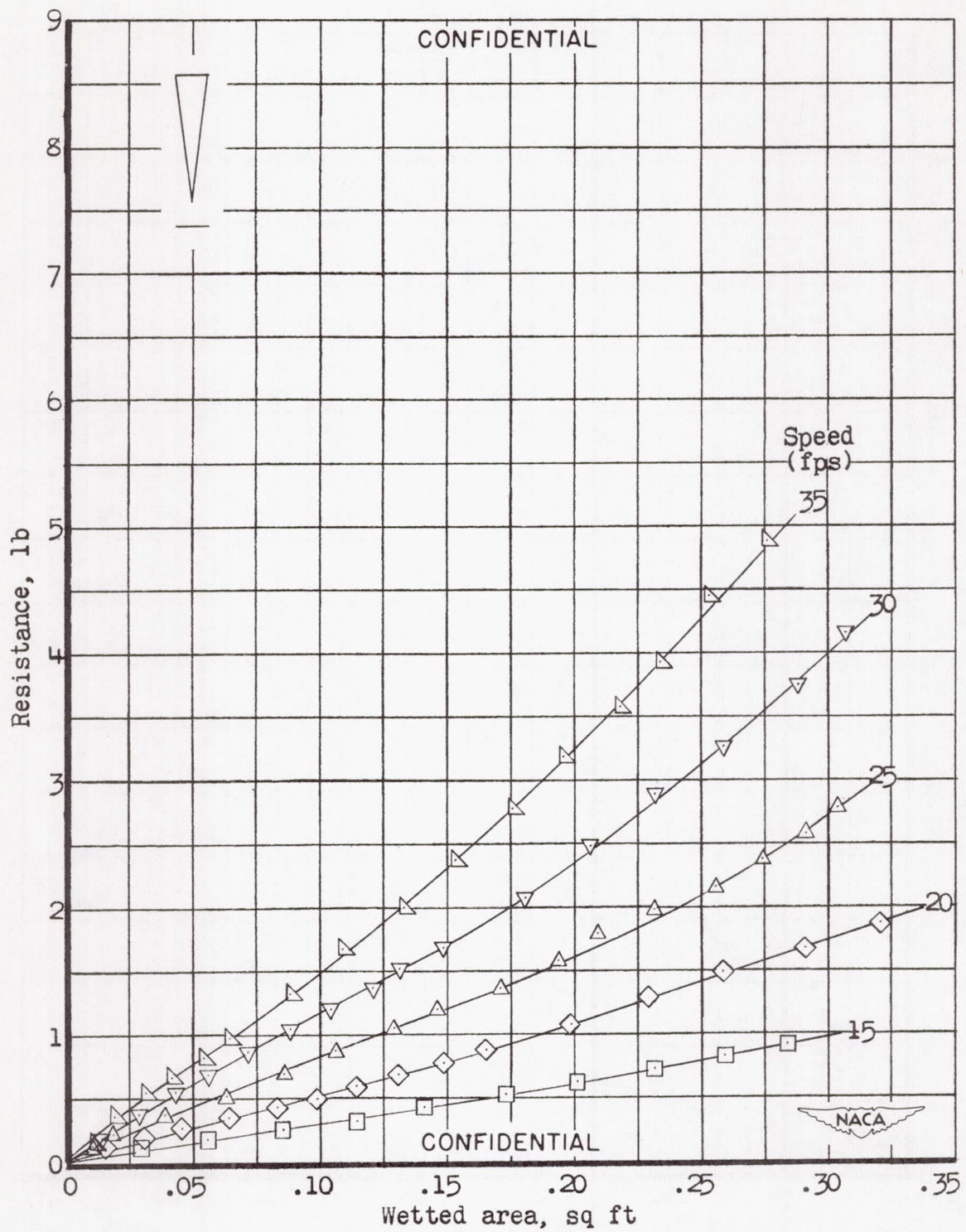
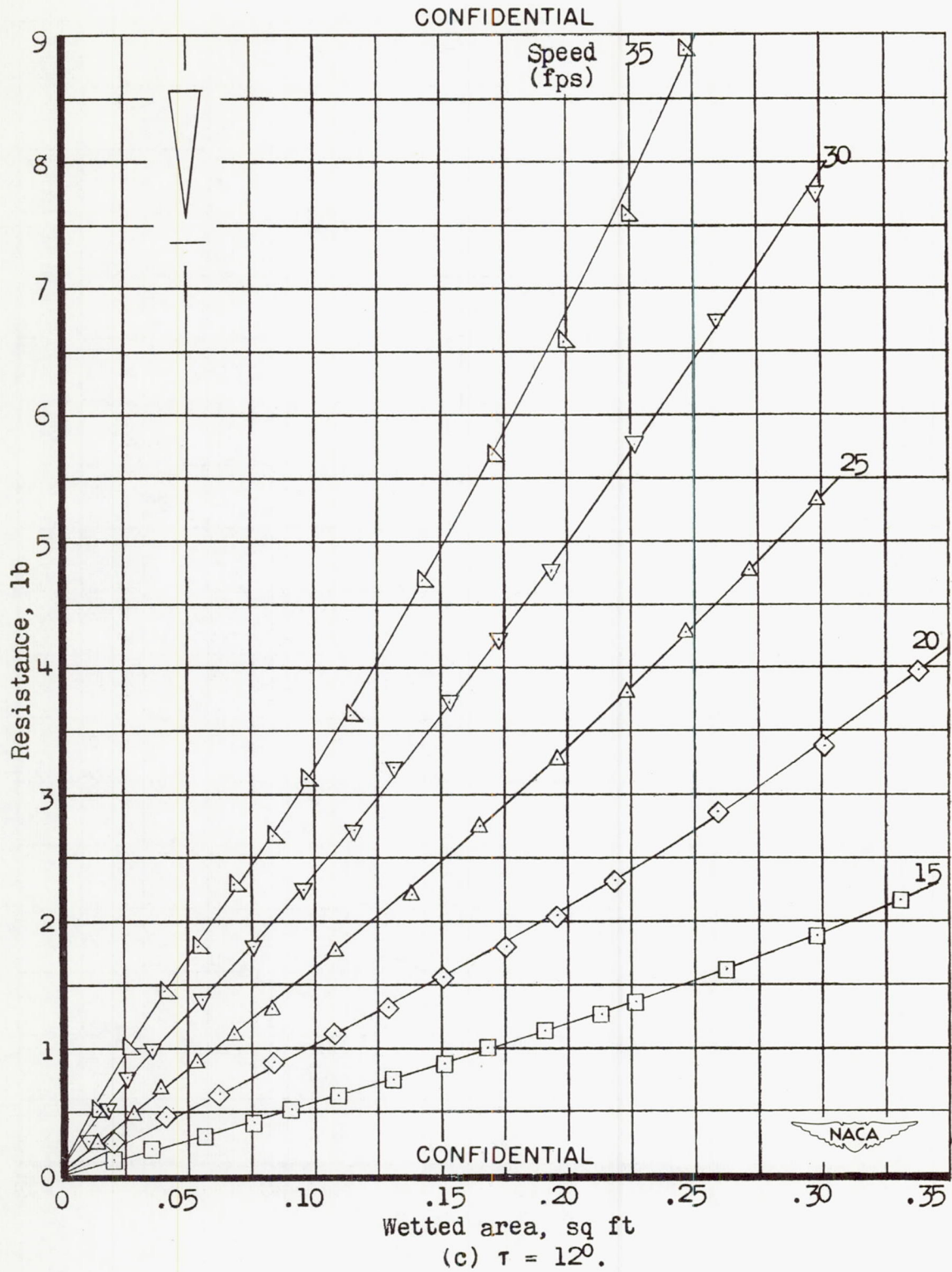


Figure 22.- Variation of resistance with wetted area. Model 250E.



(b) $\tau = 8^\circ$.

Figure 22.- Continued.



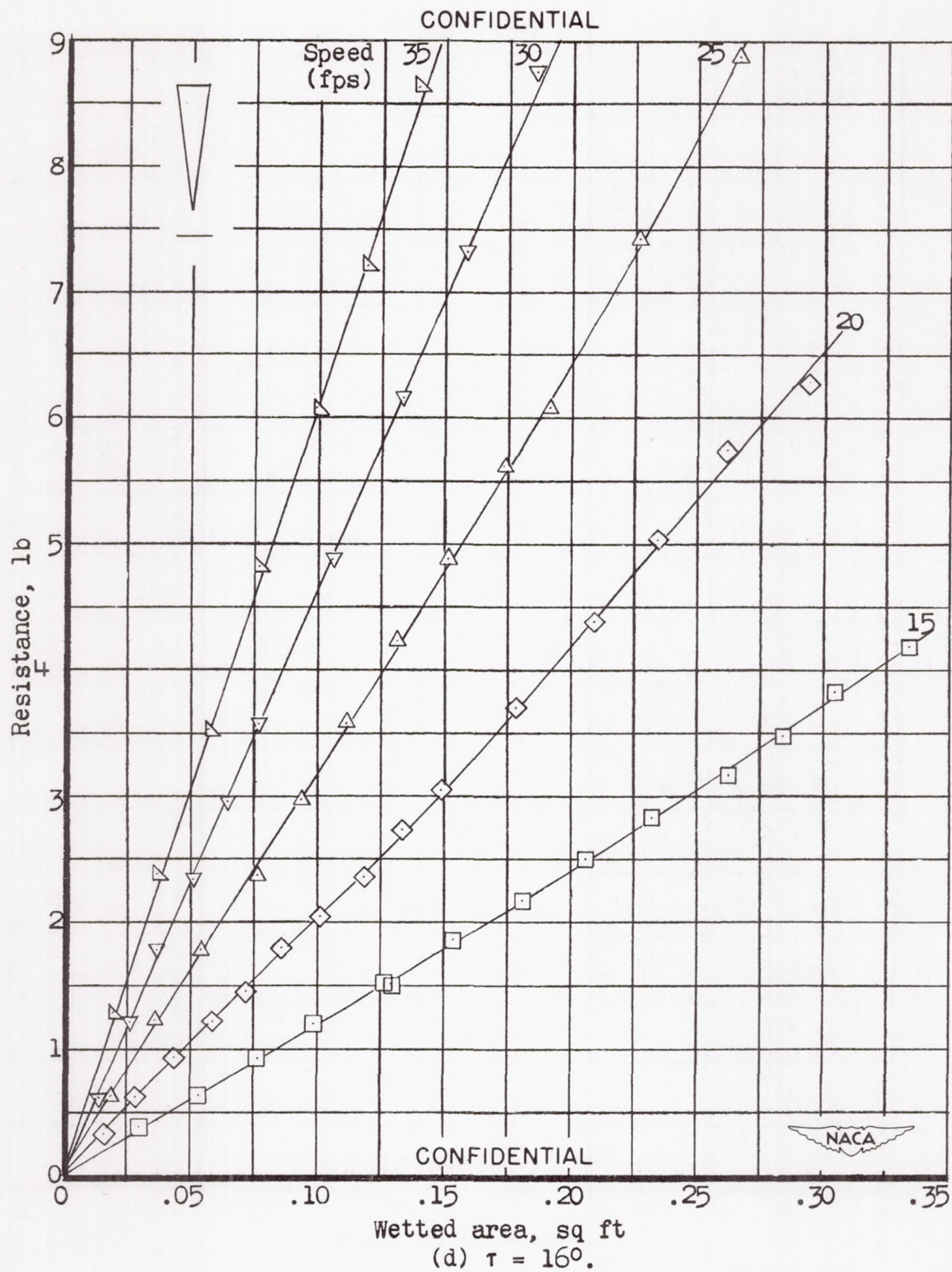
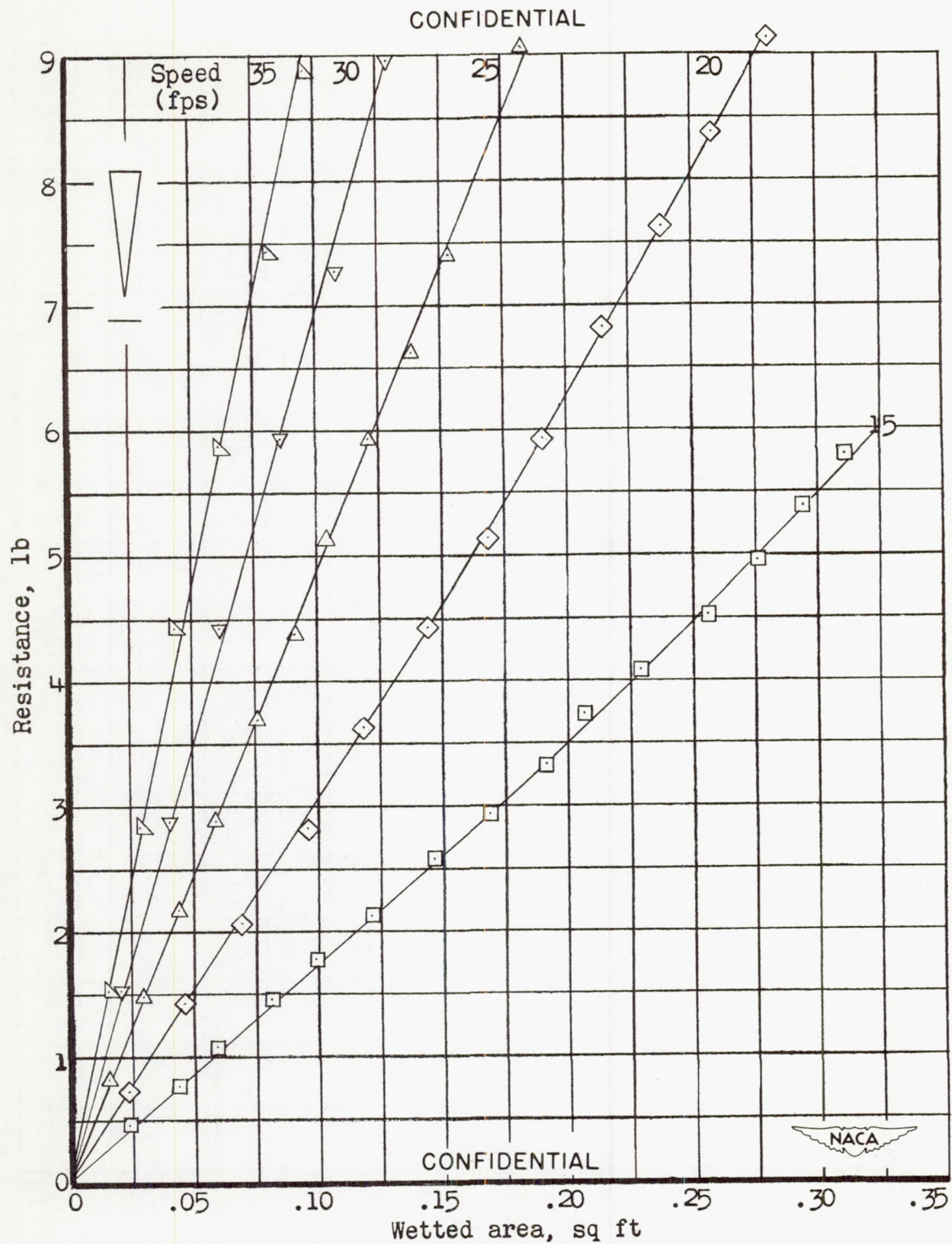


Figure 22.- Continued.



(e) $\tau = 20^\circ$.
Figure 22.- Concluded.

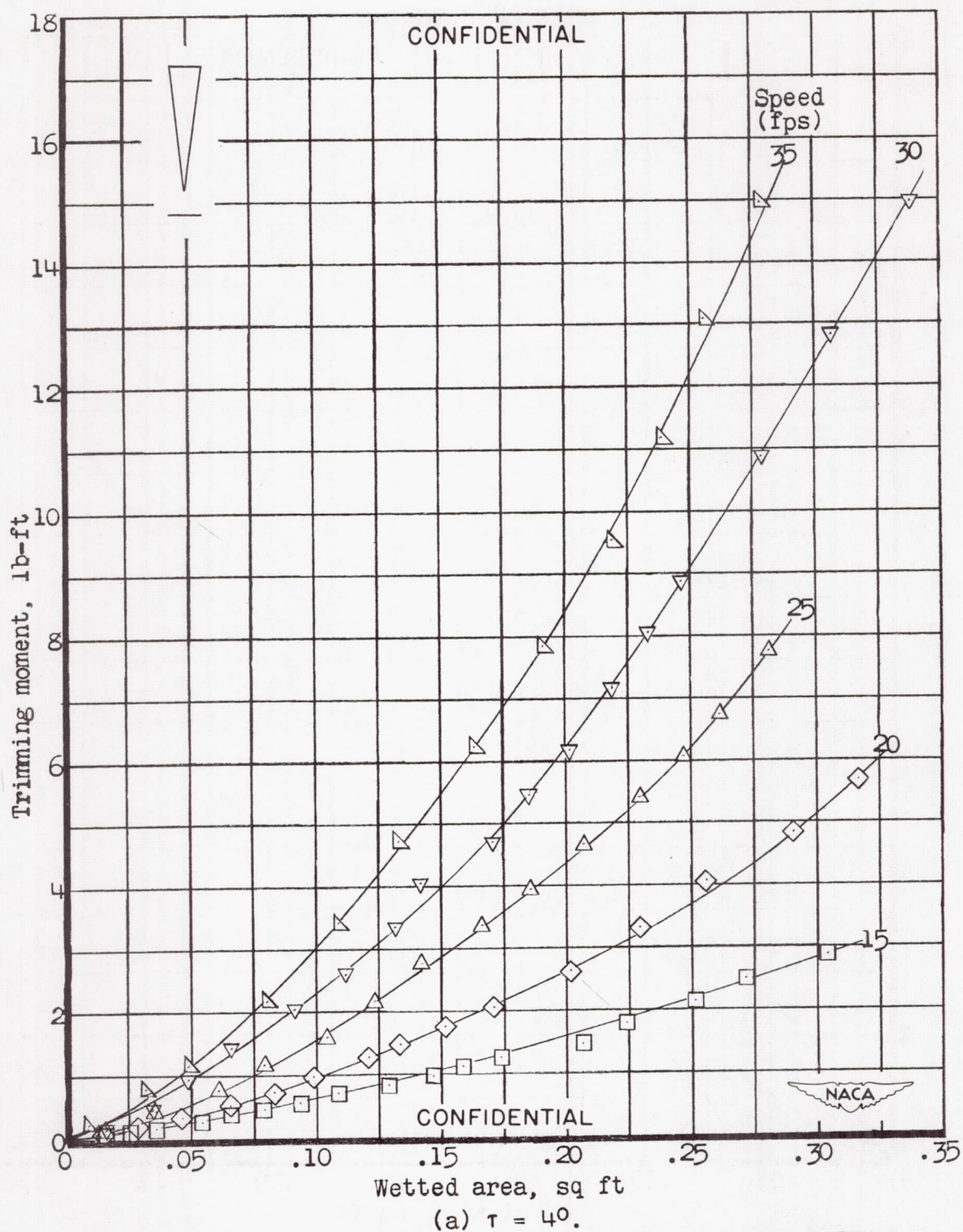


Figure 23.- Variation of moment with wetted area. Model 250E.

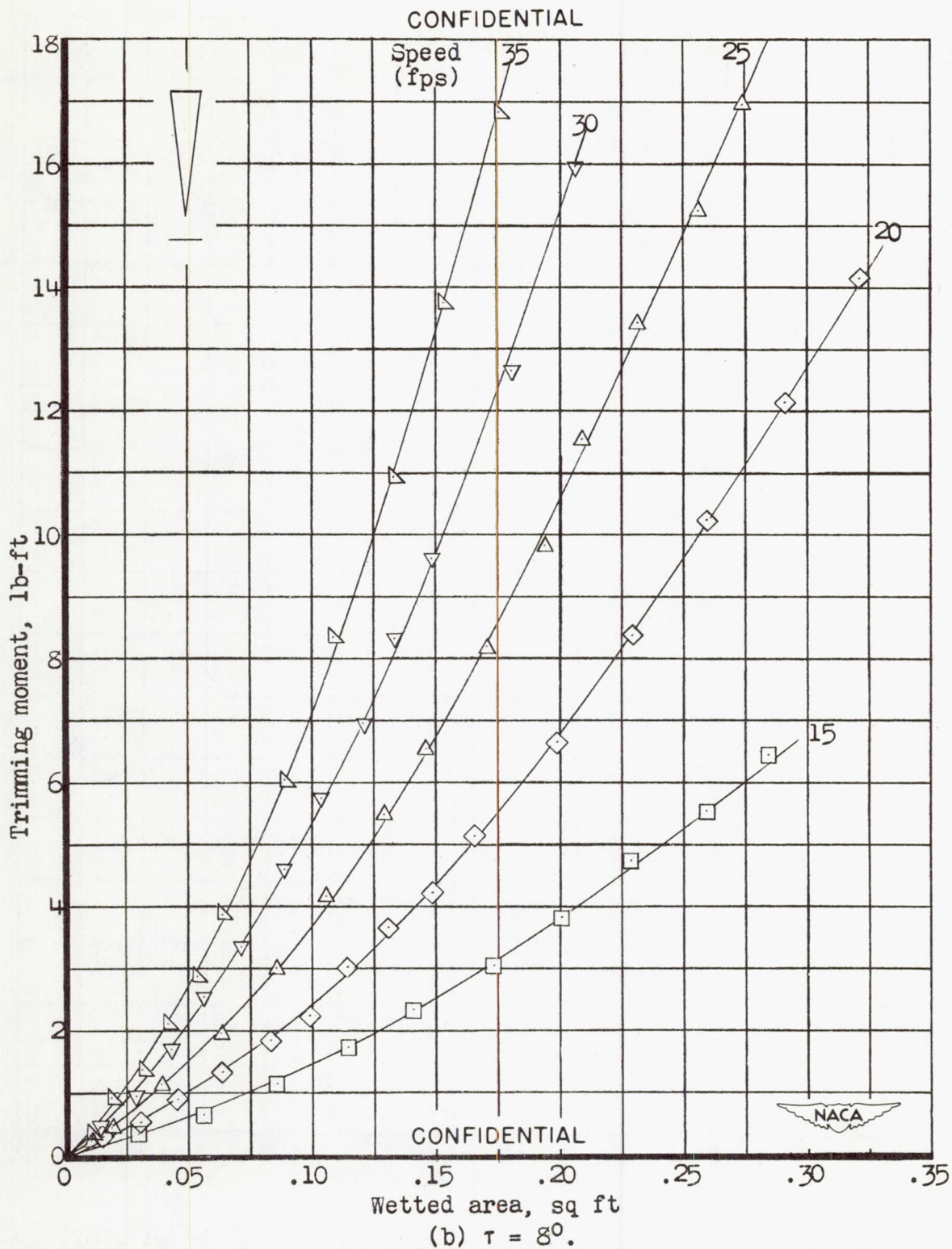
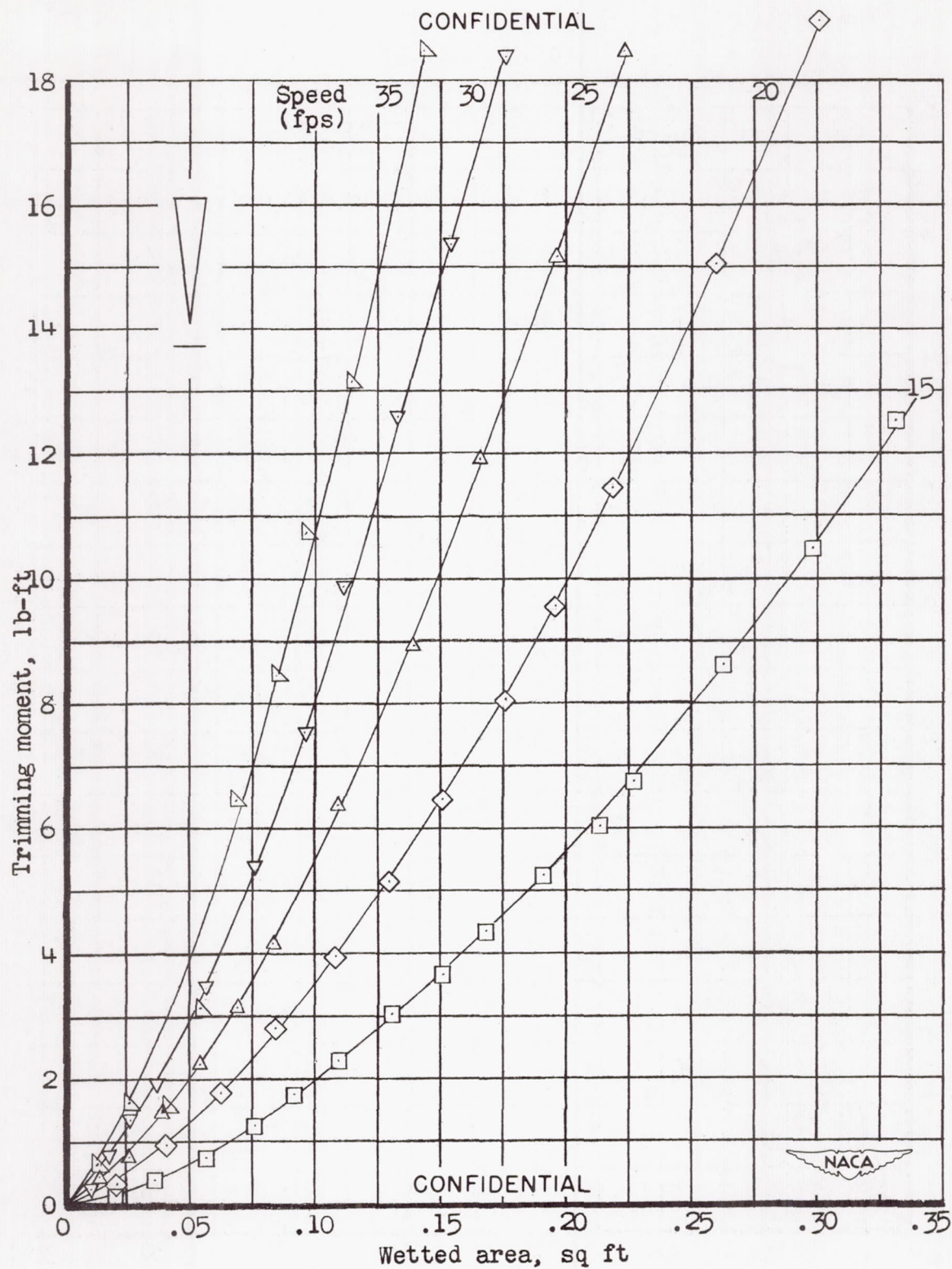


Figure 23.- Continued.



(c) $\tau = 12^\circ$.
Figure 23.- Continued.

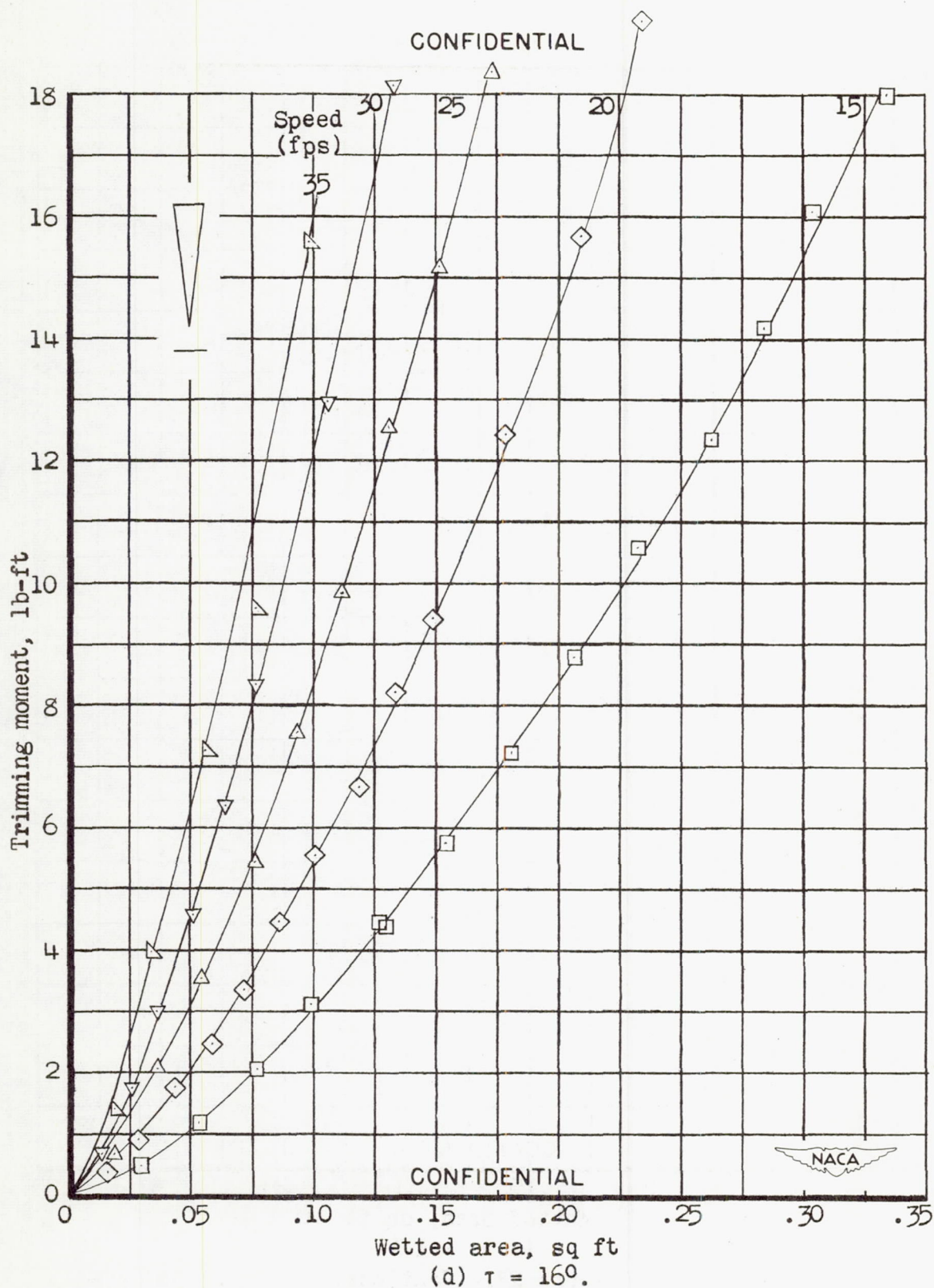
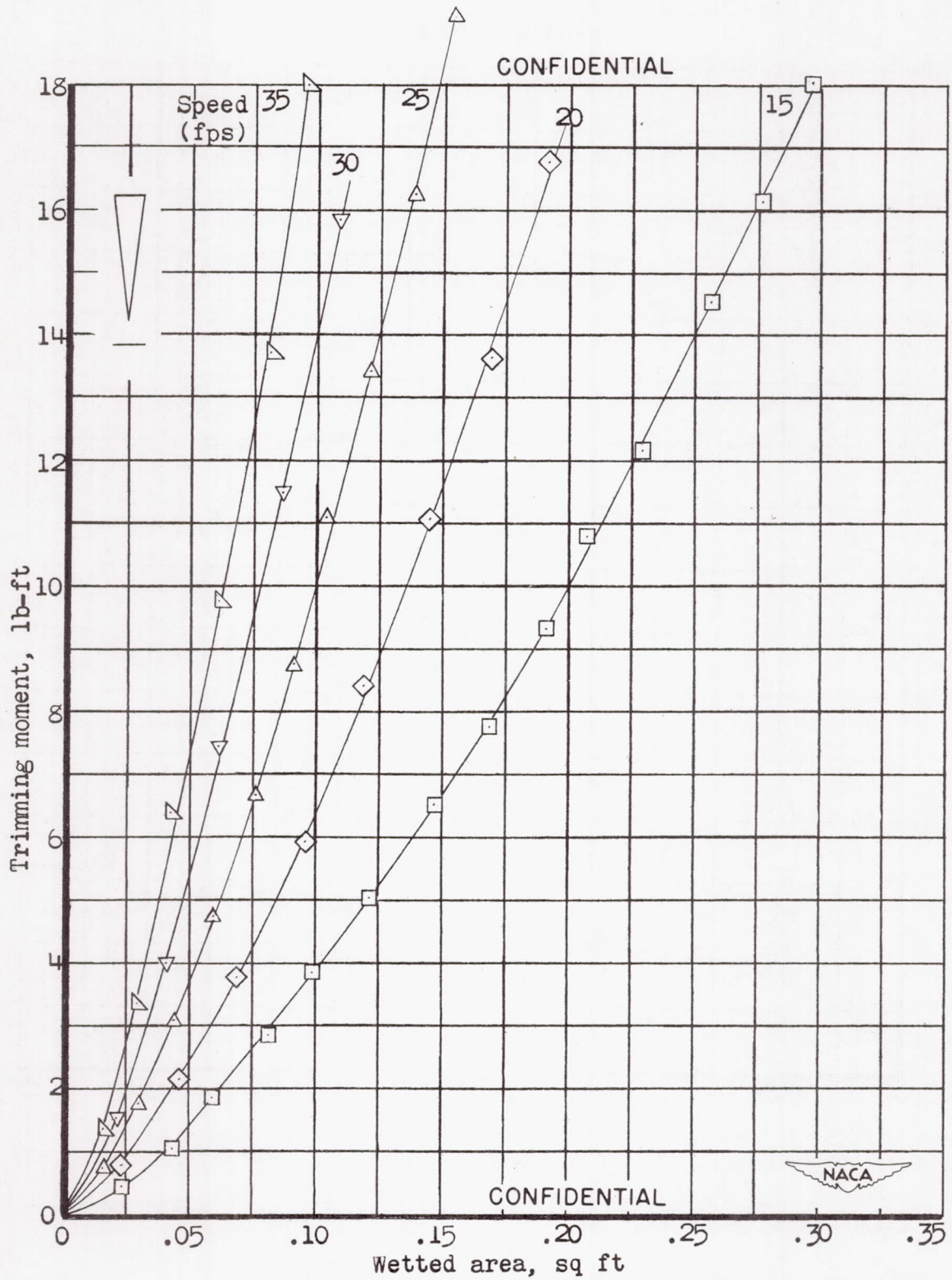


Figure 23.- Continued.



(e) $\tau = 20^\circ$.
Figure 23.- Concluded.

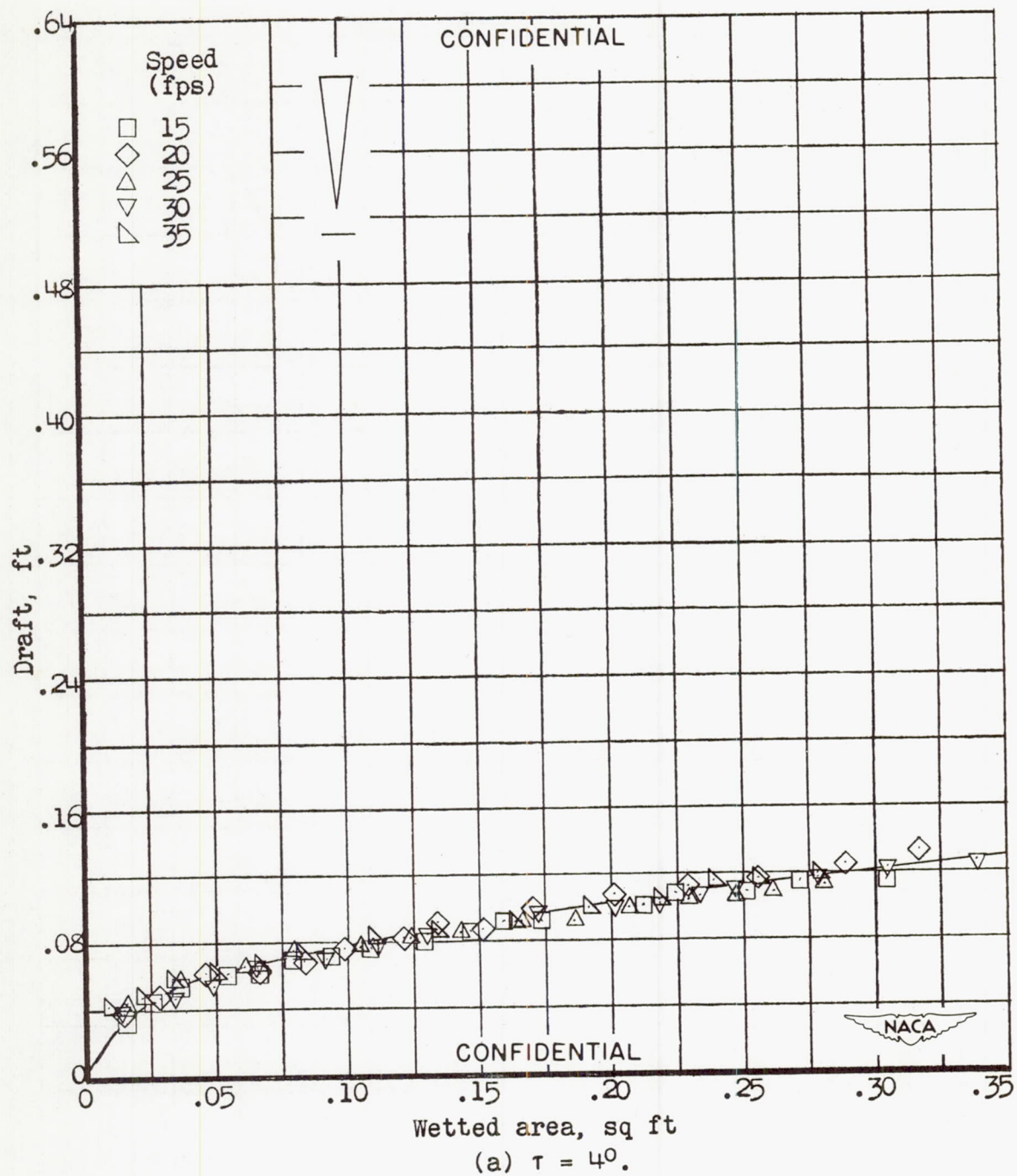
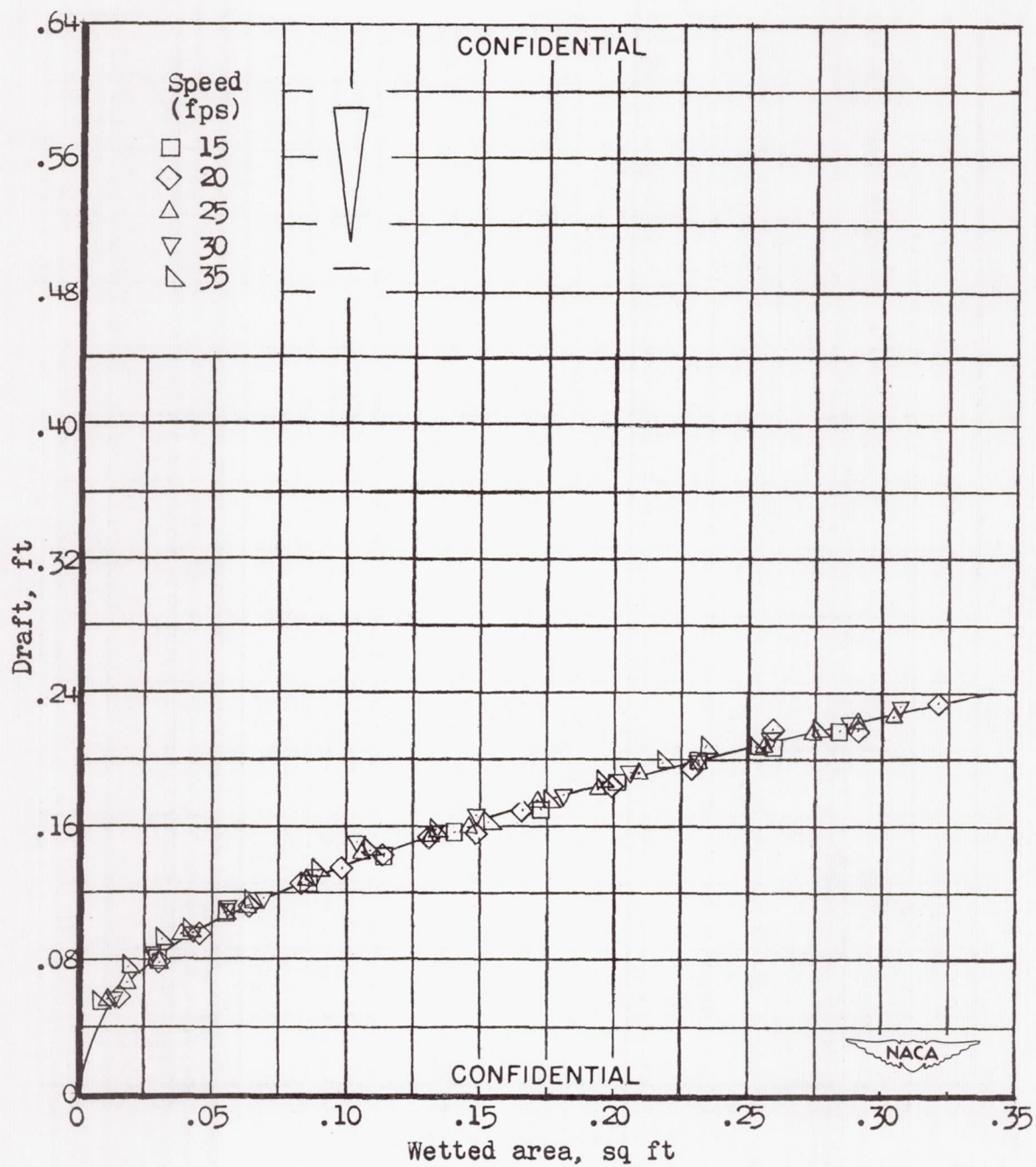
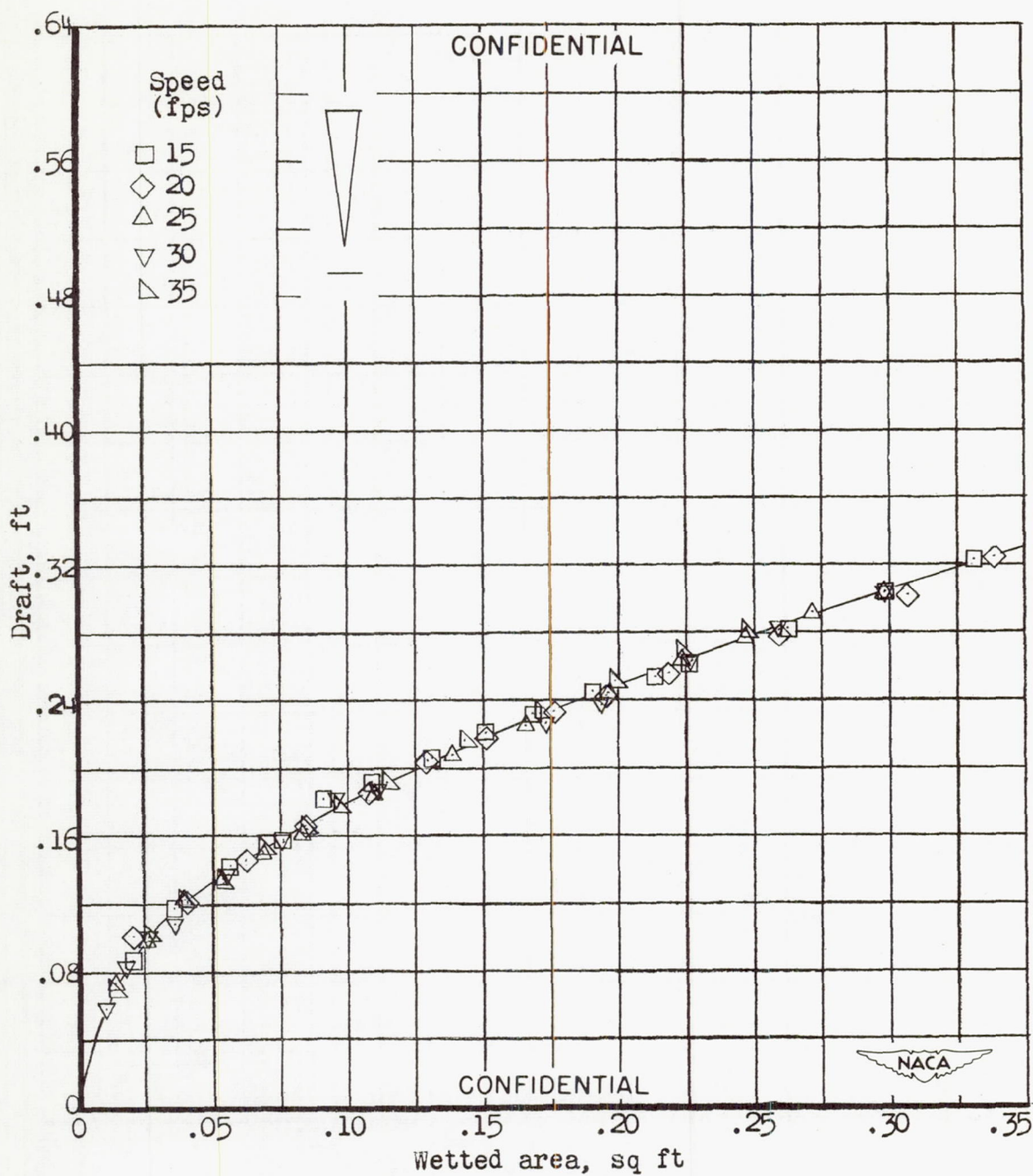


Figure 24.- Variation of draft with wetted area. Model 250E.



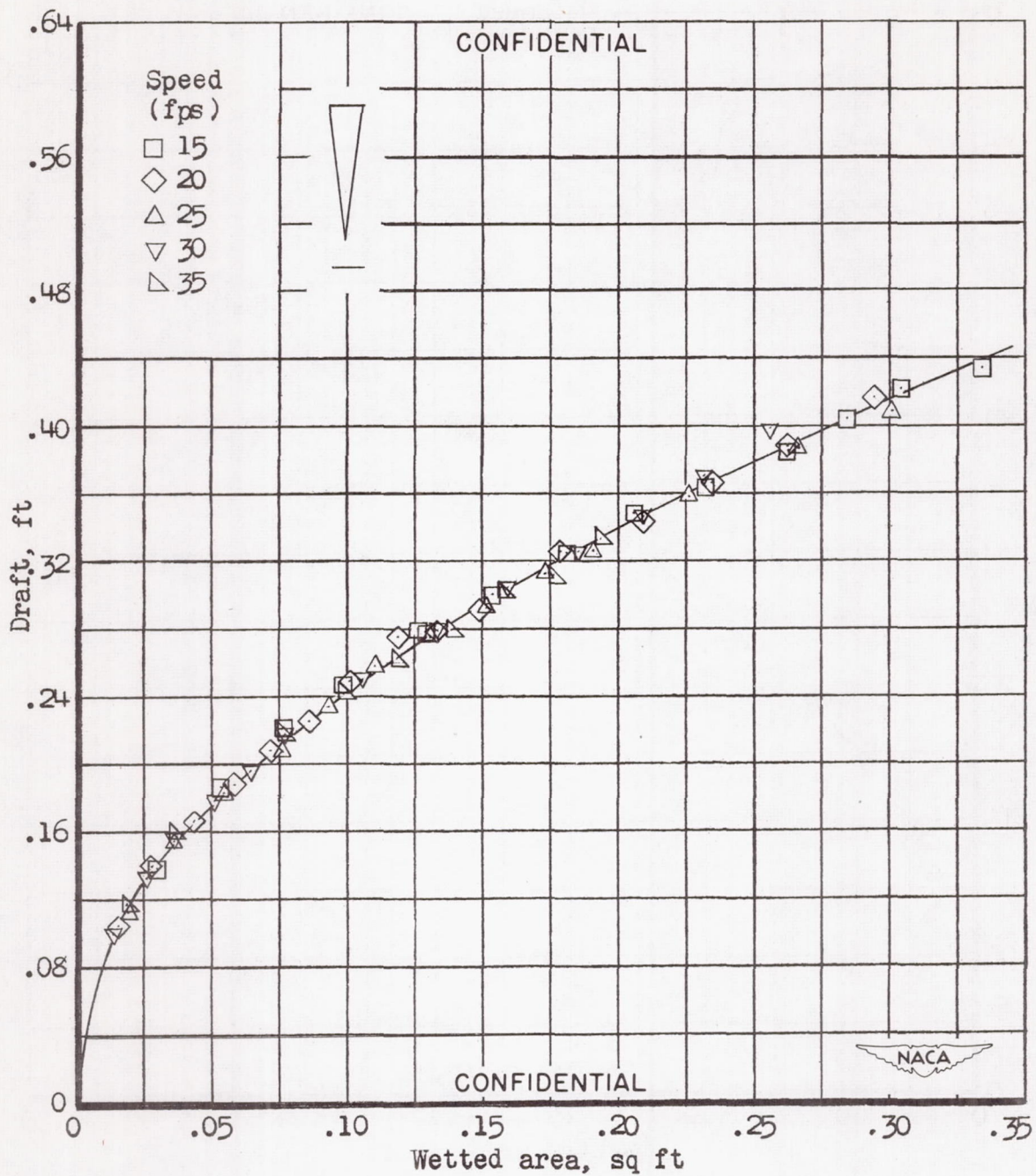
(b) $\tau = 8^\circ$.

Figure 24.- Continued.



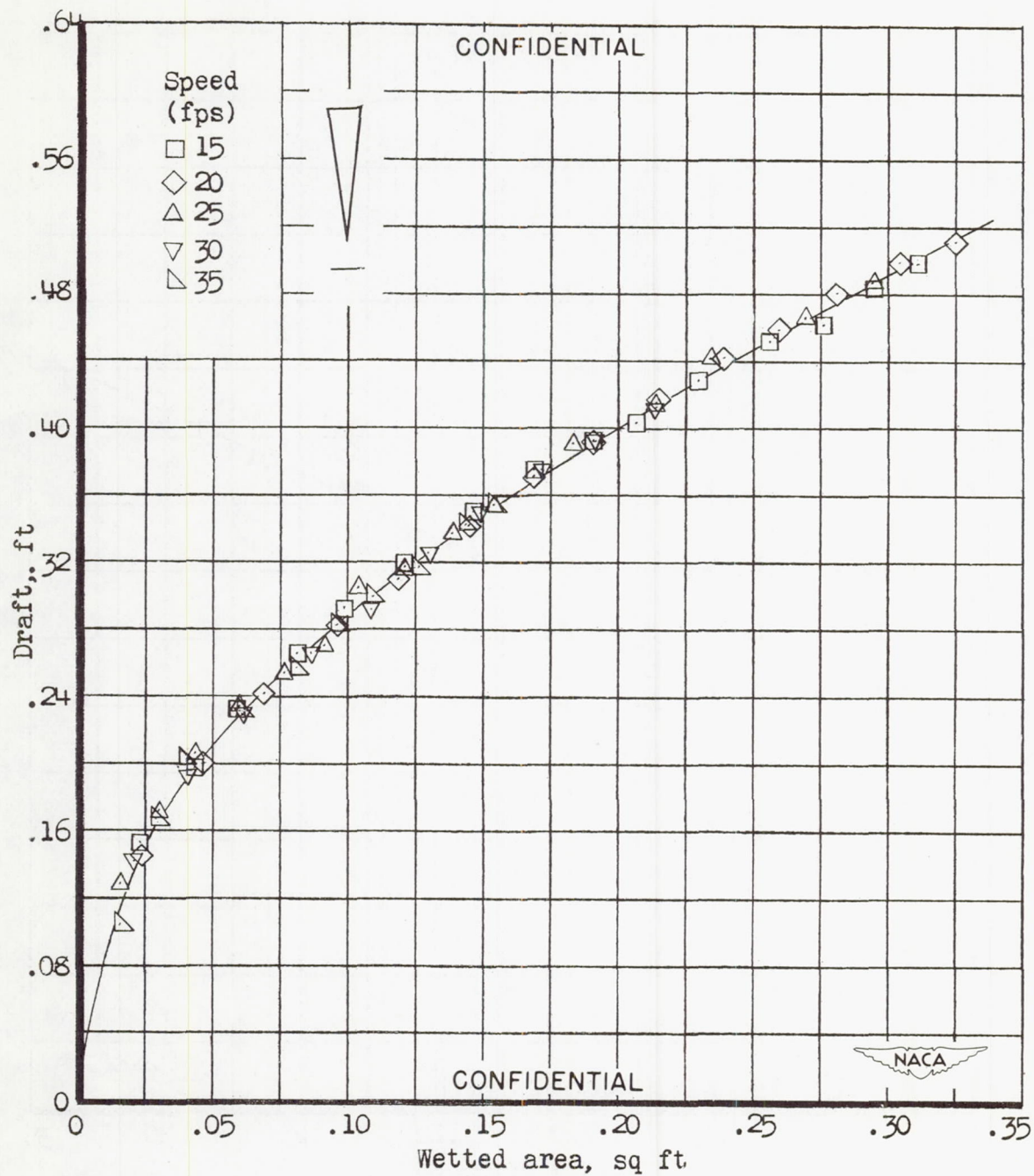
(c) $\tau = 12^\circ$.

Figure 24.- Continued.



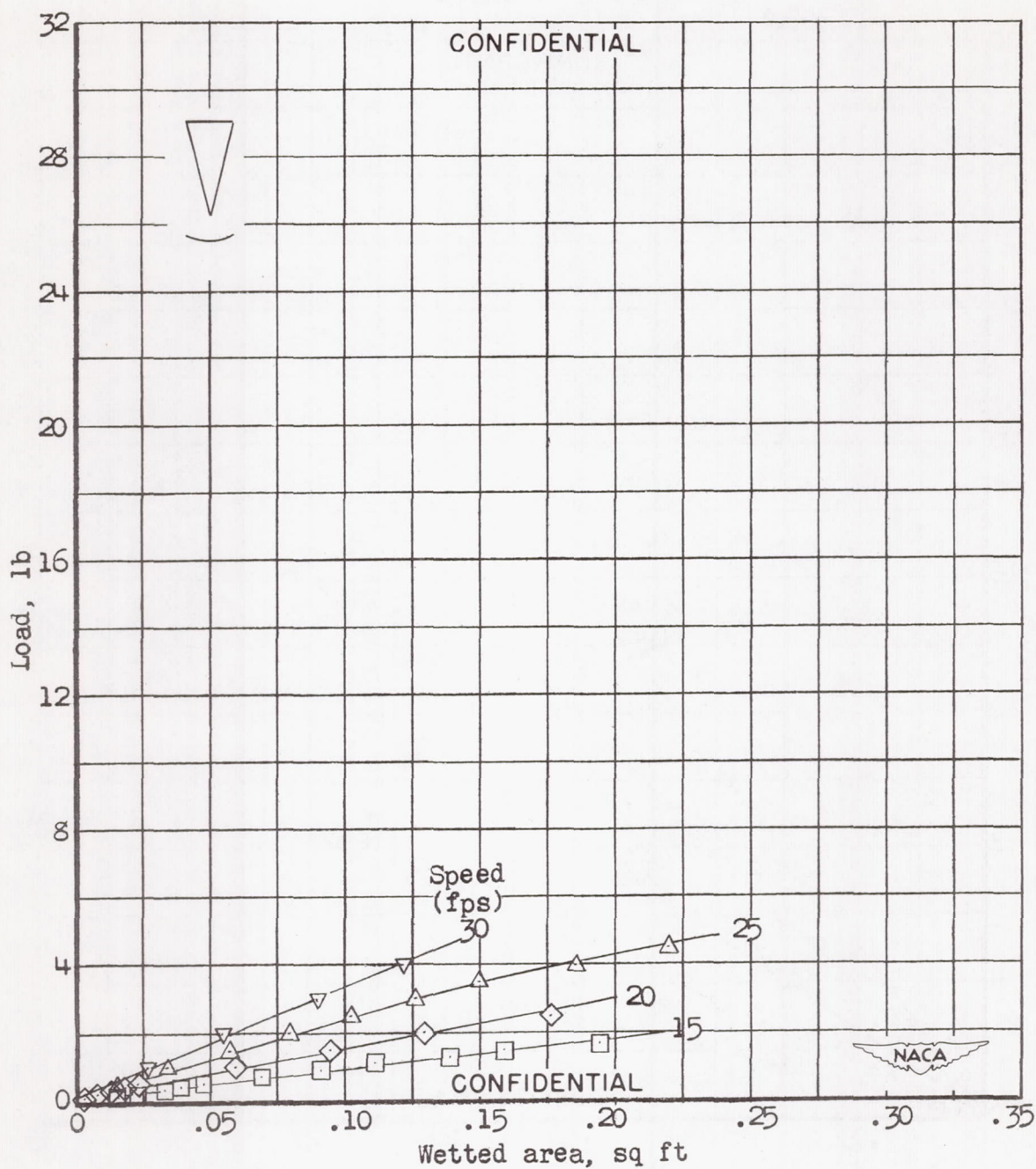
(d) $\tau = 16^\circ$.

Figure 24.- Continued.



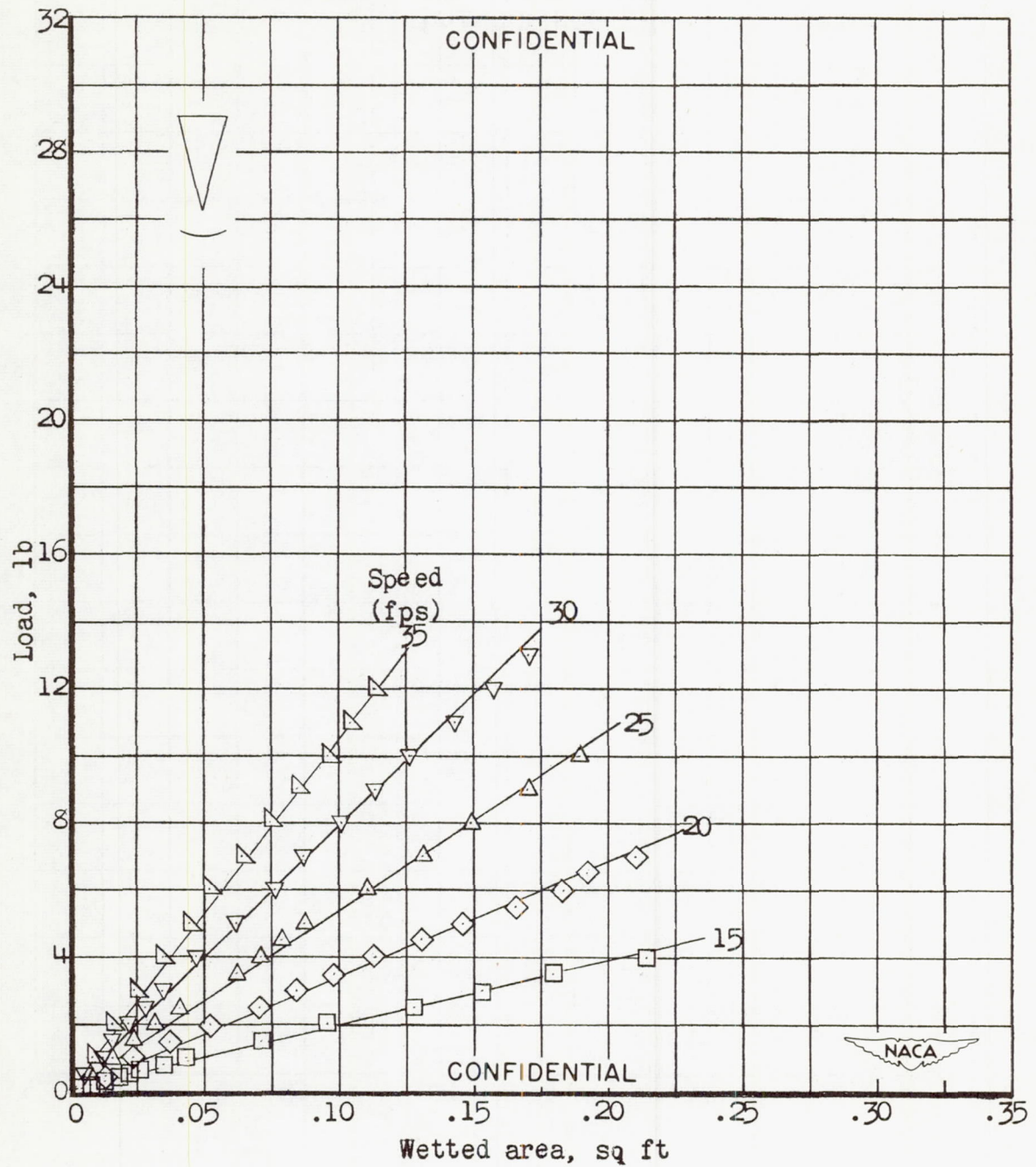
(e) $\tau = 20^\circ$.

Figure 24.- Concluded.



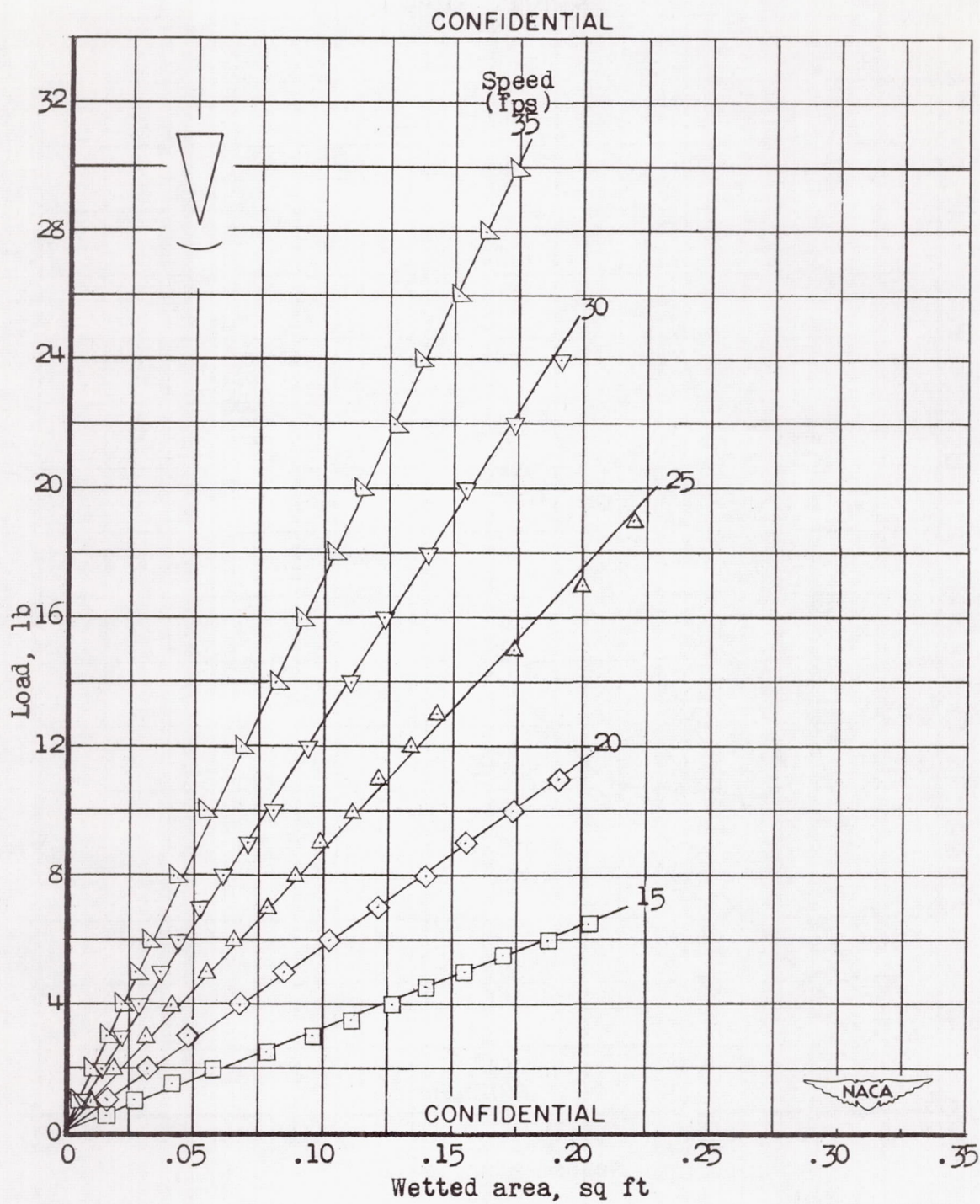
(a) $\tau = 40^\circ$.

Figure 25.- Variation of load with wetted area. Model 250F.



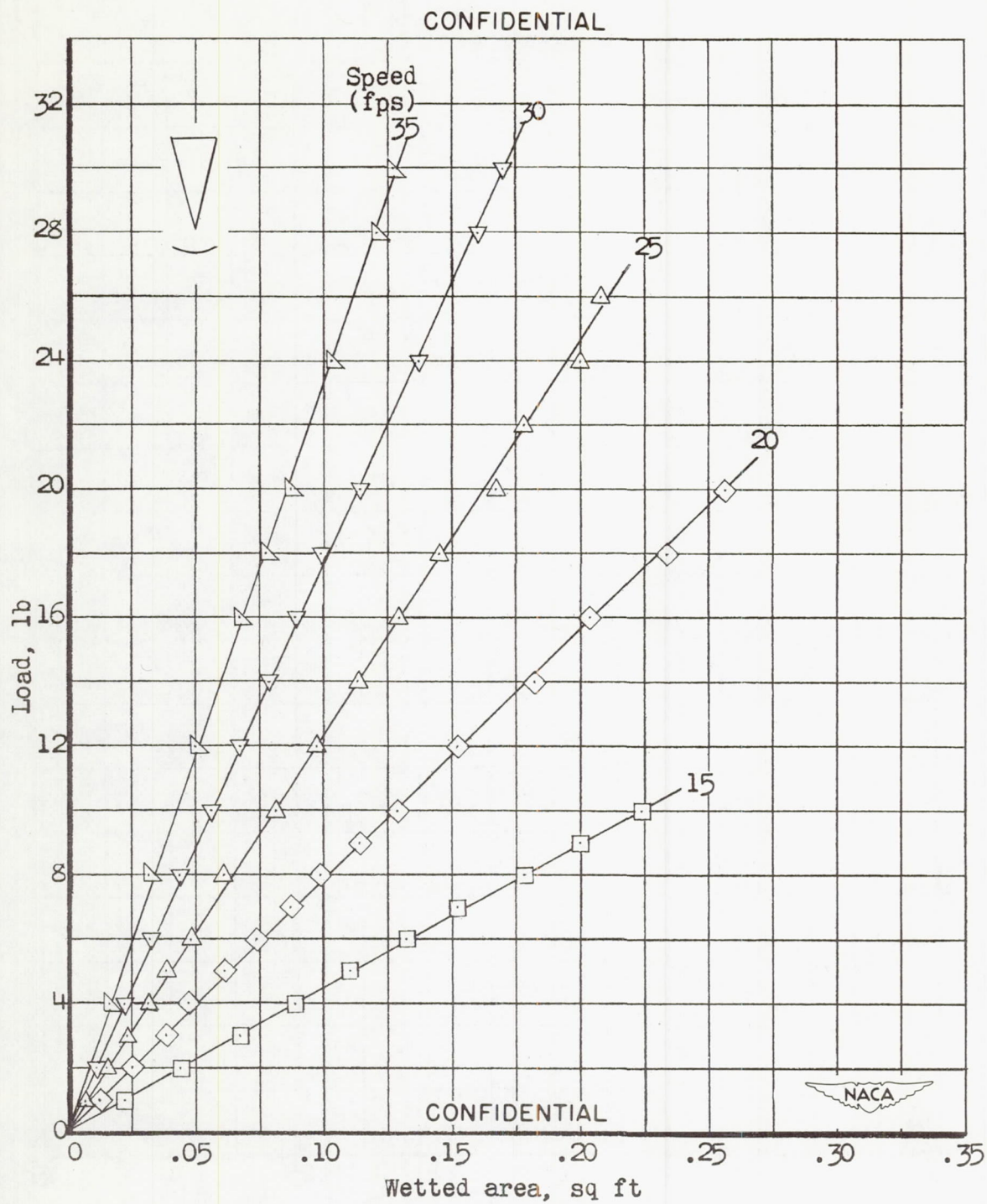
(b) $\tau = 8^\circ$.

Figure 25.- Continued.



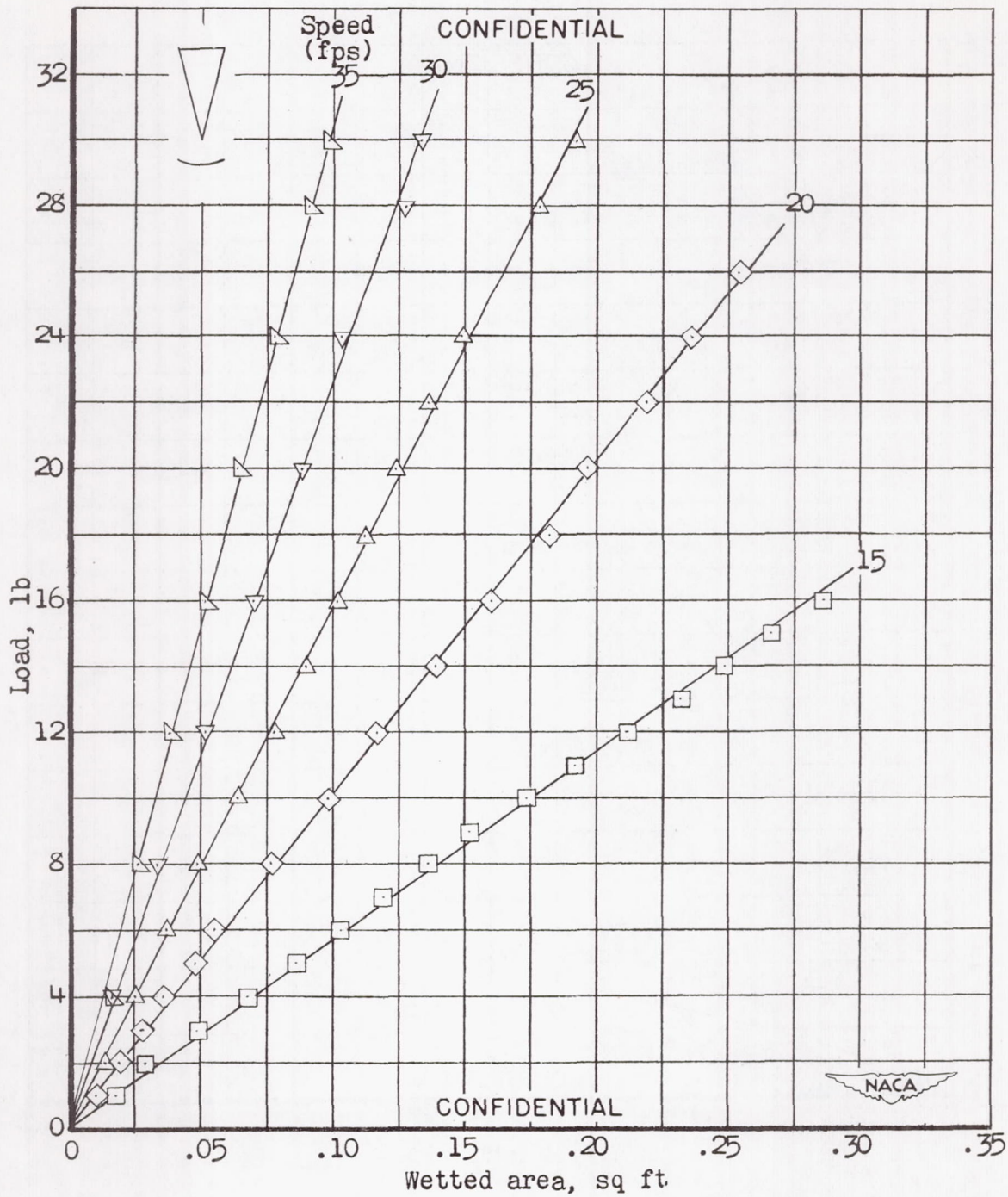
(c) $\tau = 120^\circ$.

Figure 25.- Continued.



(d) $\tau = 16^\circ$.

Figure 25.- Continued.



(e) $\tau = 20^\circ$.

Figure 25.- Concluded.

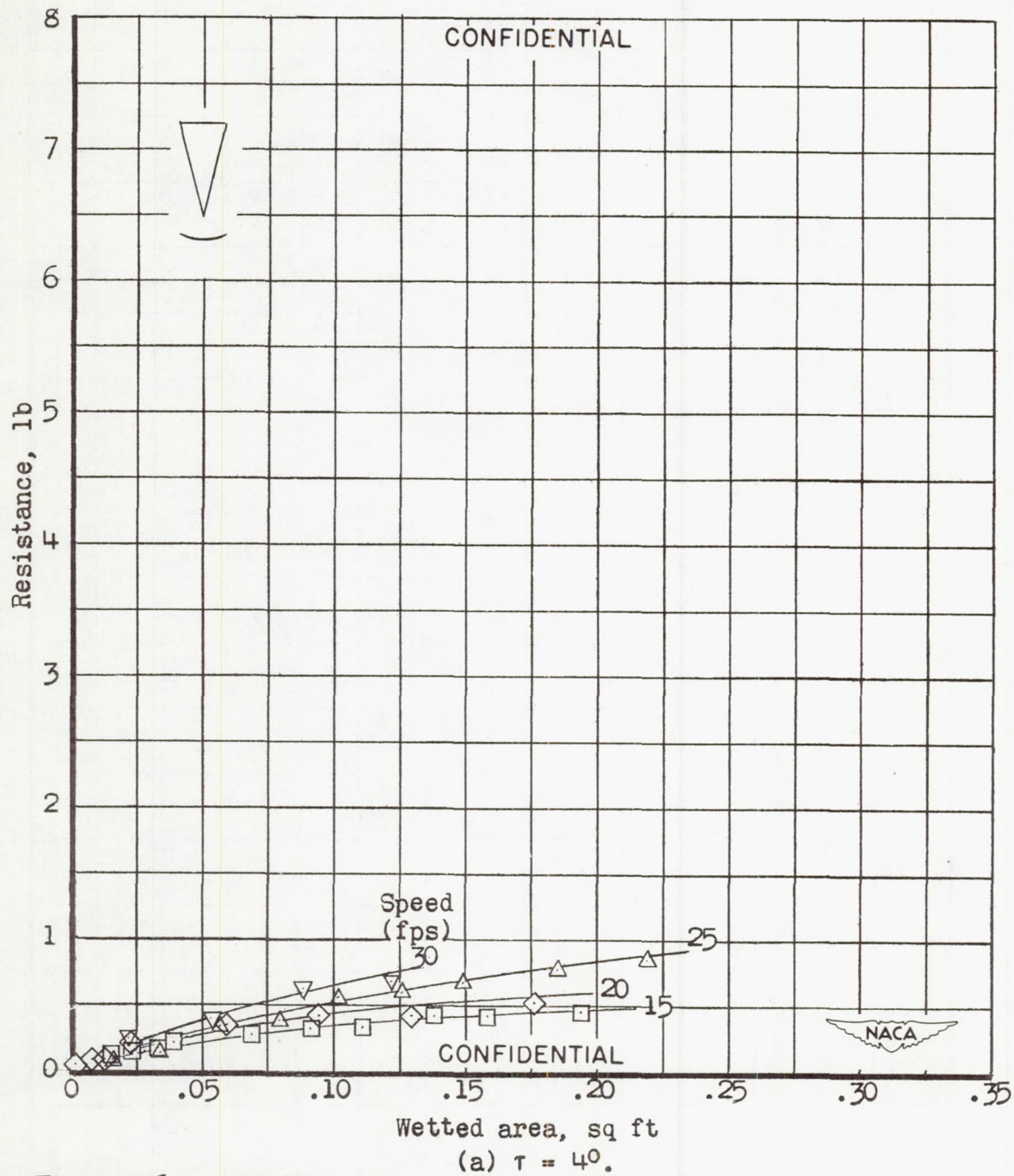


Figure 26.- Variation of resistance with wetted area. Model 250F.

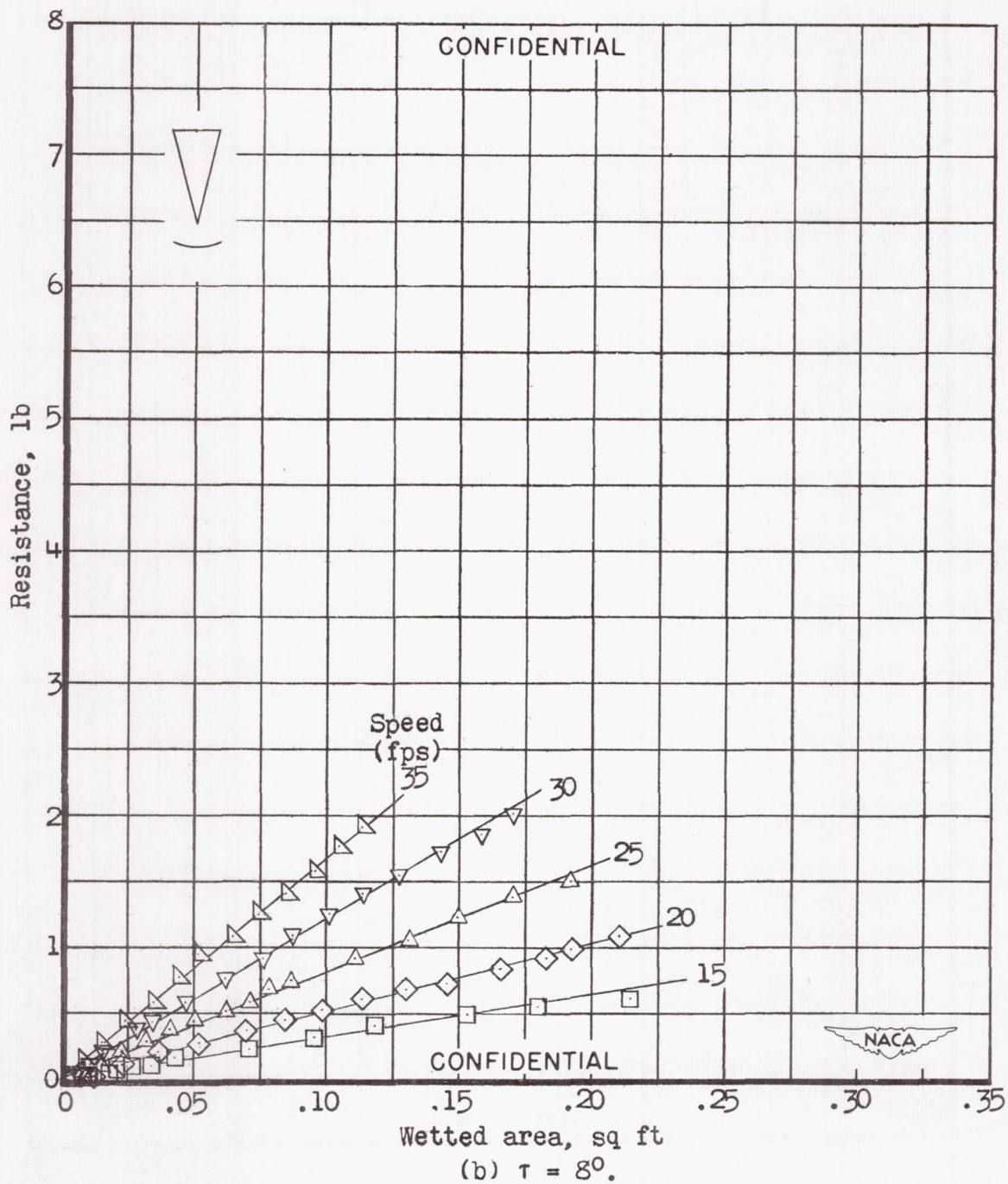
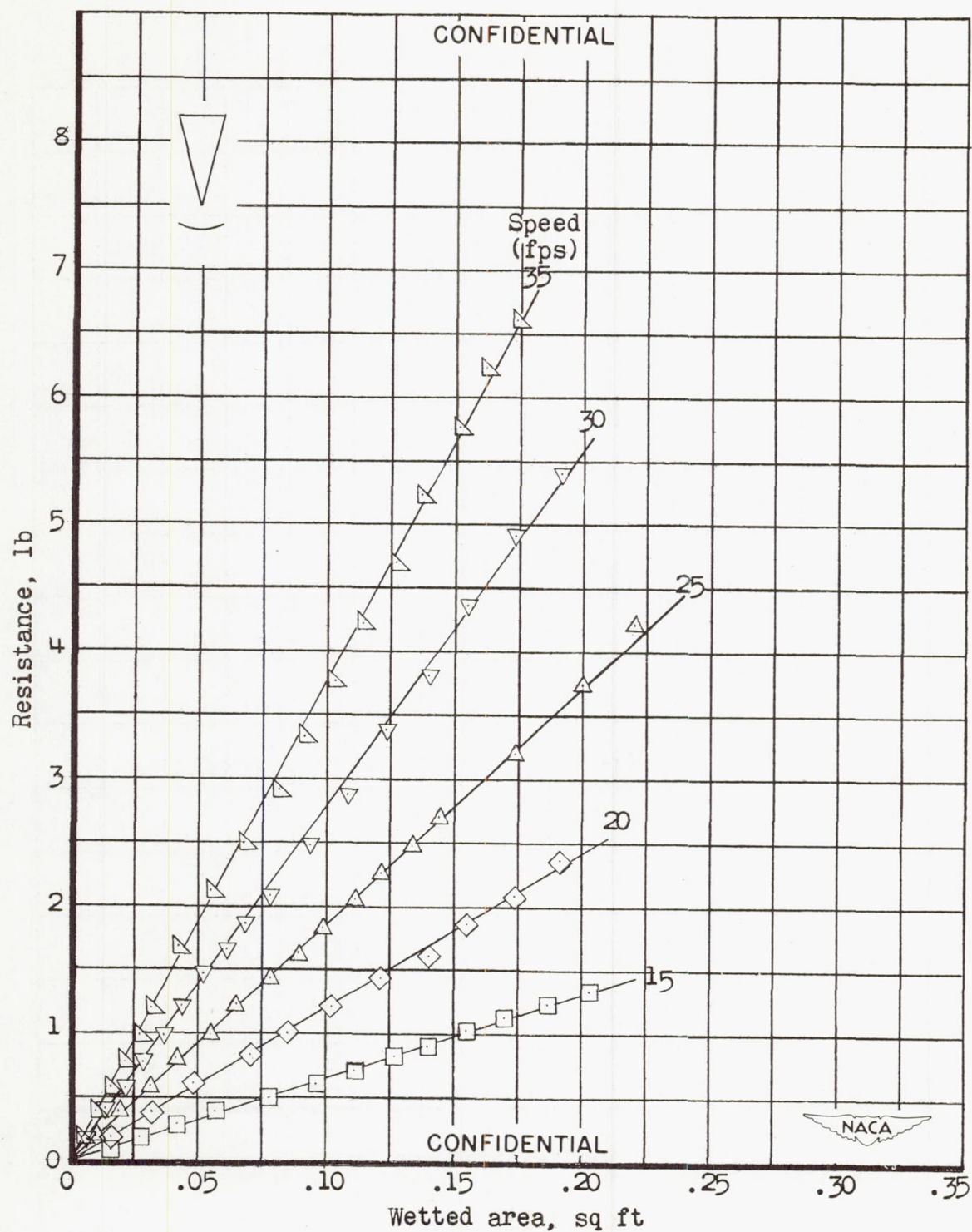
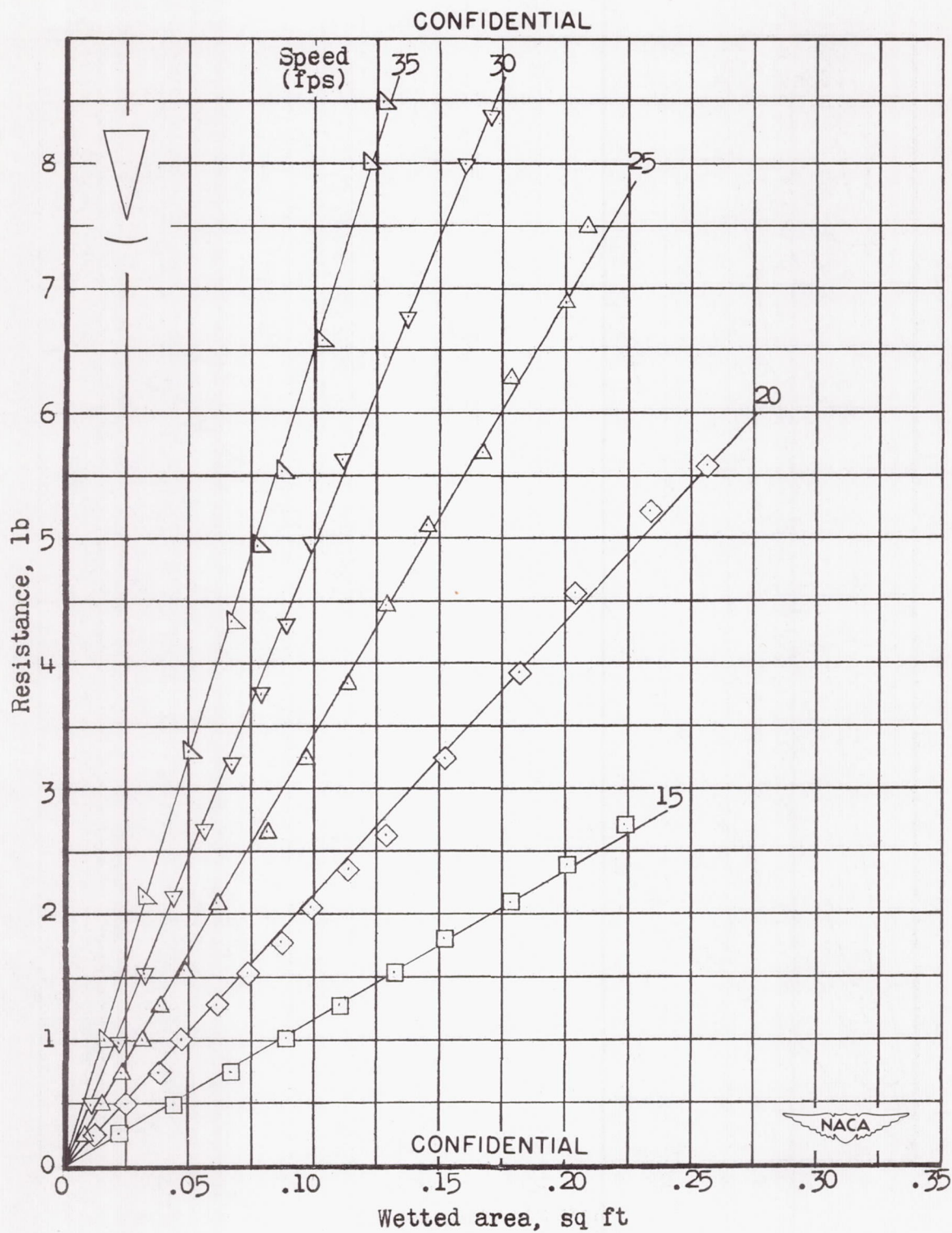


Figure 26.- Continued.



(c) $\tau = 12^\circ$.

Figure 26.- Continued.



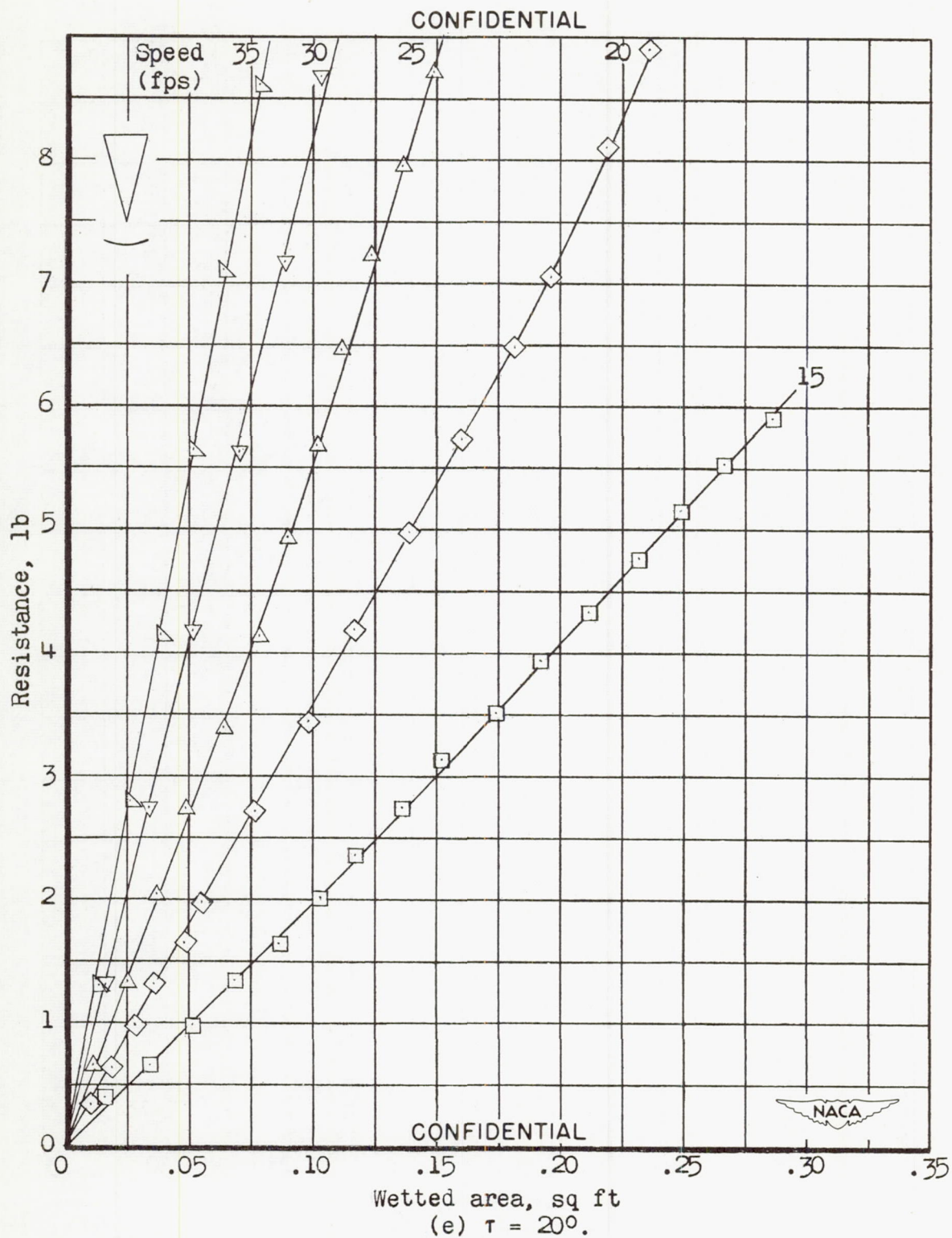


Figure 26.- Concluded.

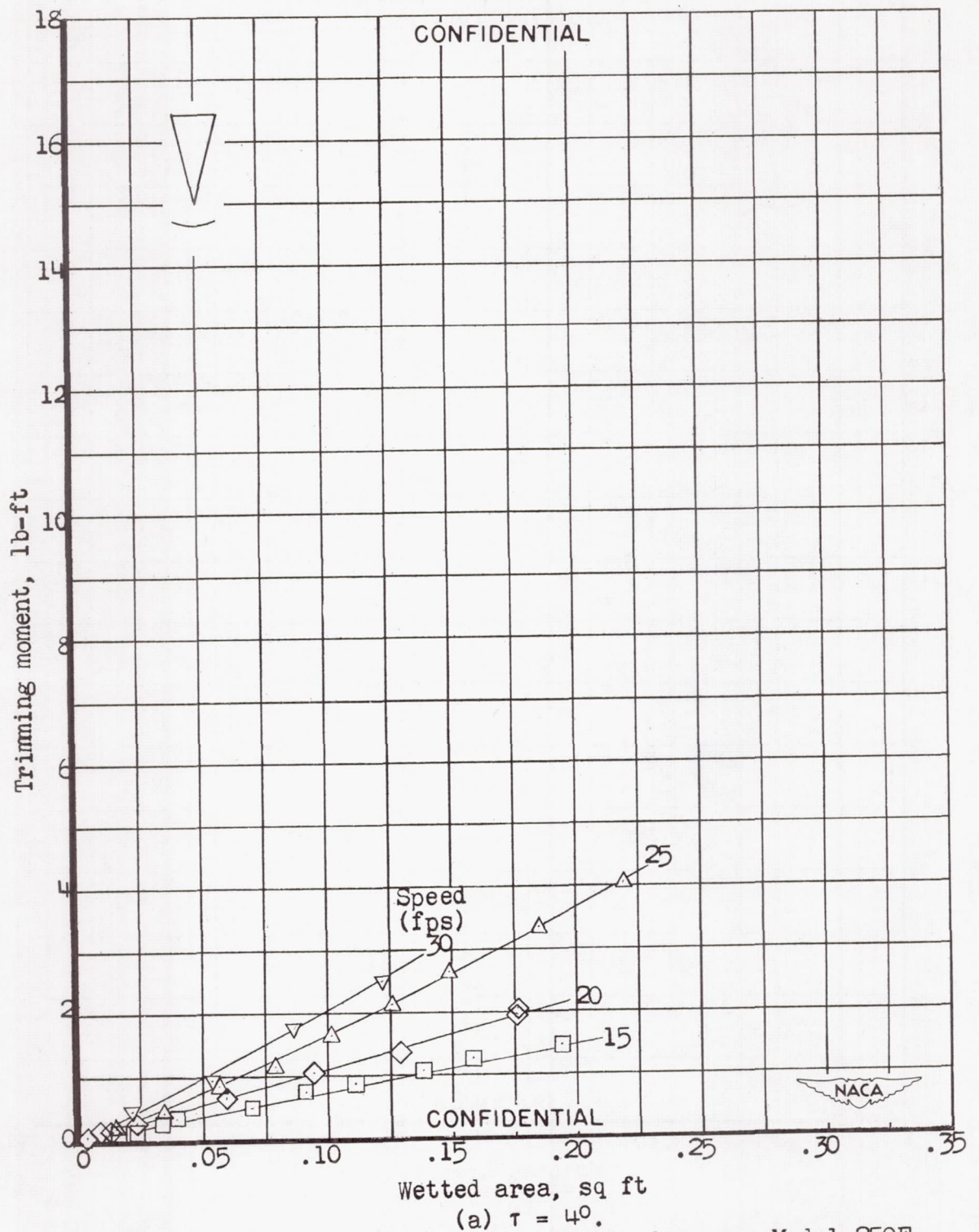
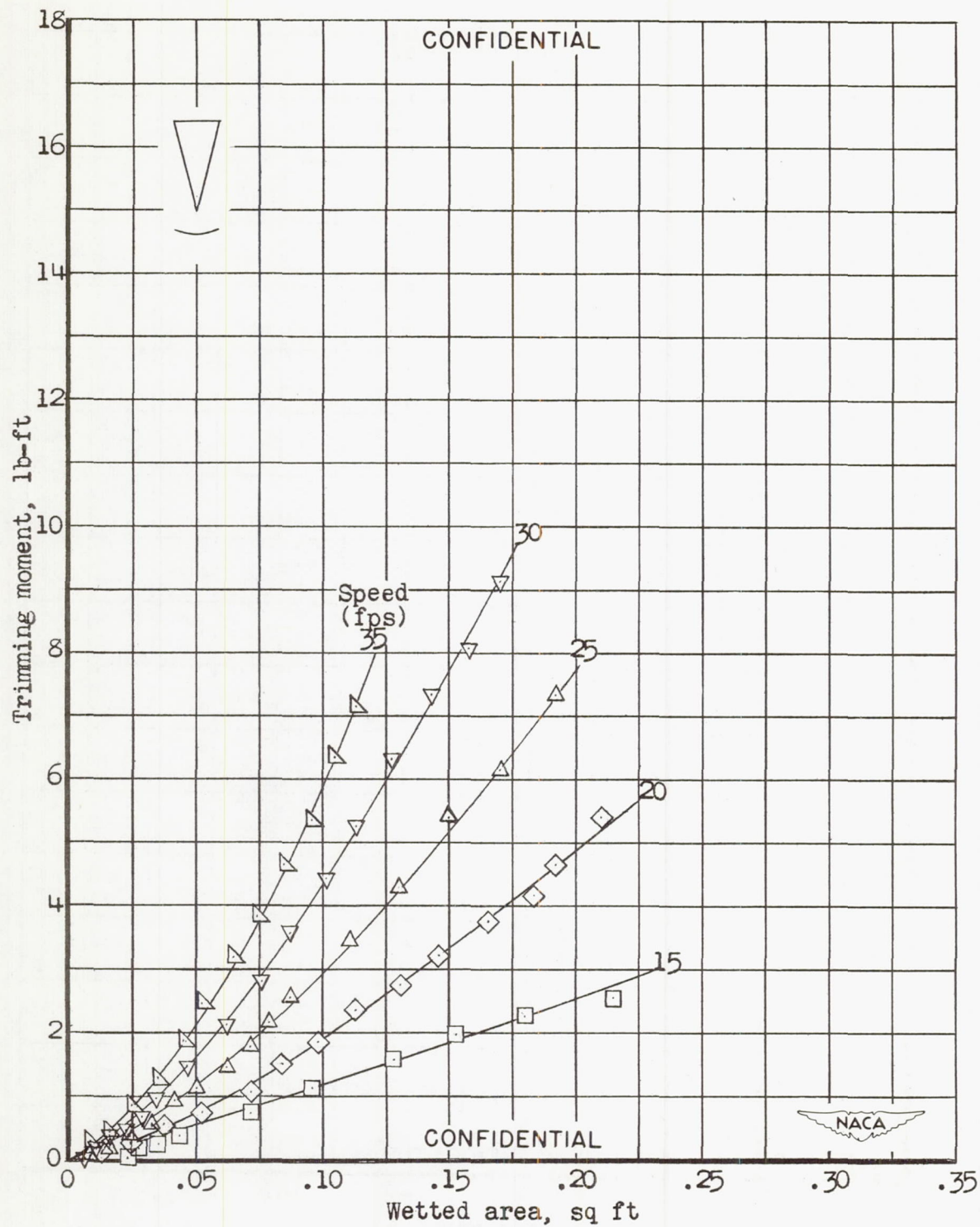


Figure 27.- Variation of moment with wetted area. Model 250F.



(b) $\tau = 8^\circ$.
Figure 27.- Continued.

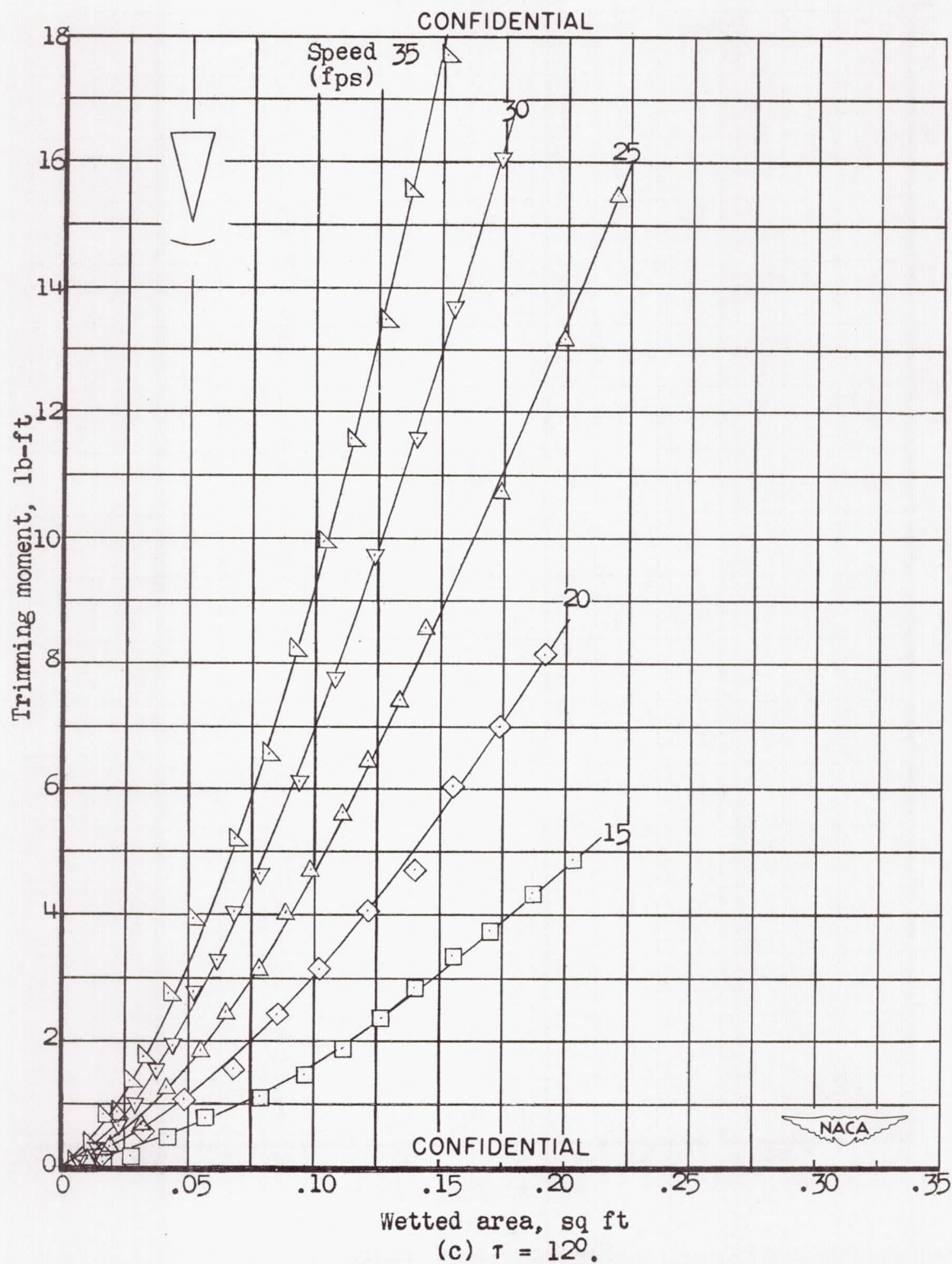
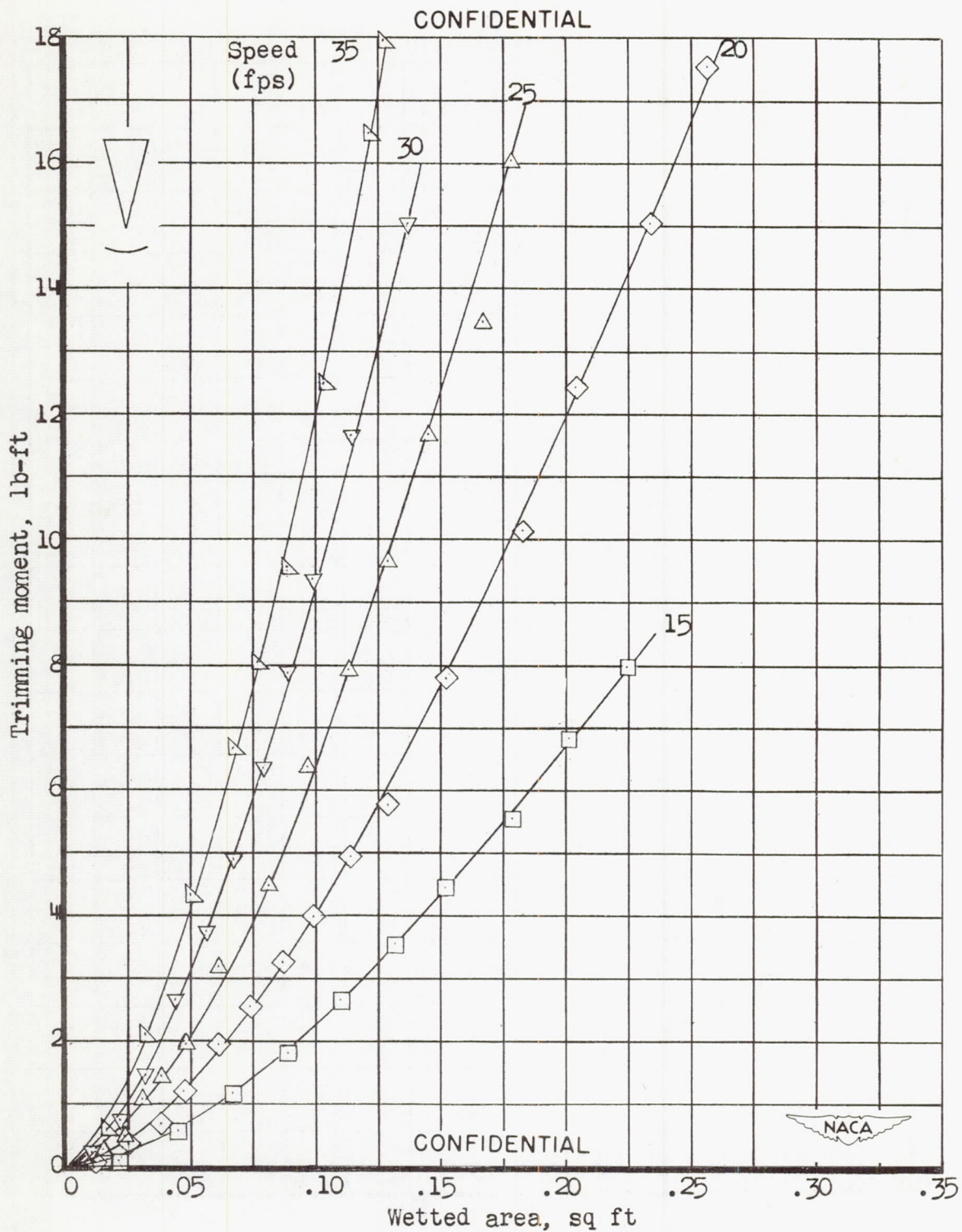


Figure 27.- Continued.



(d) $\tau = 16^\circ$.
Figure 27.- Continued.

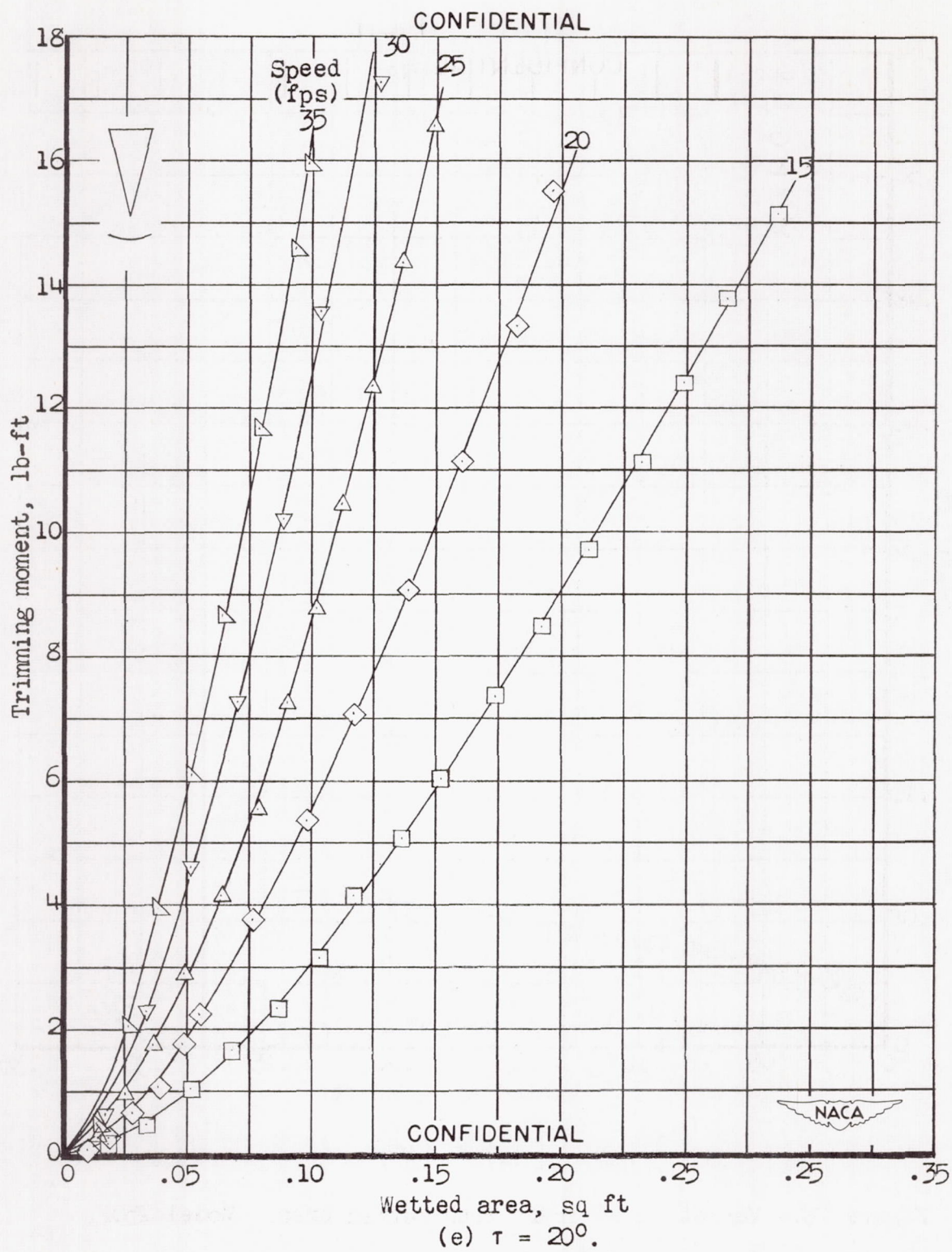
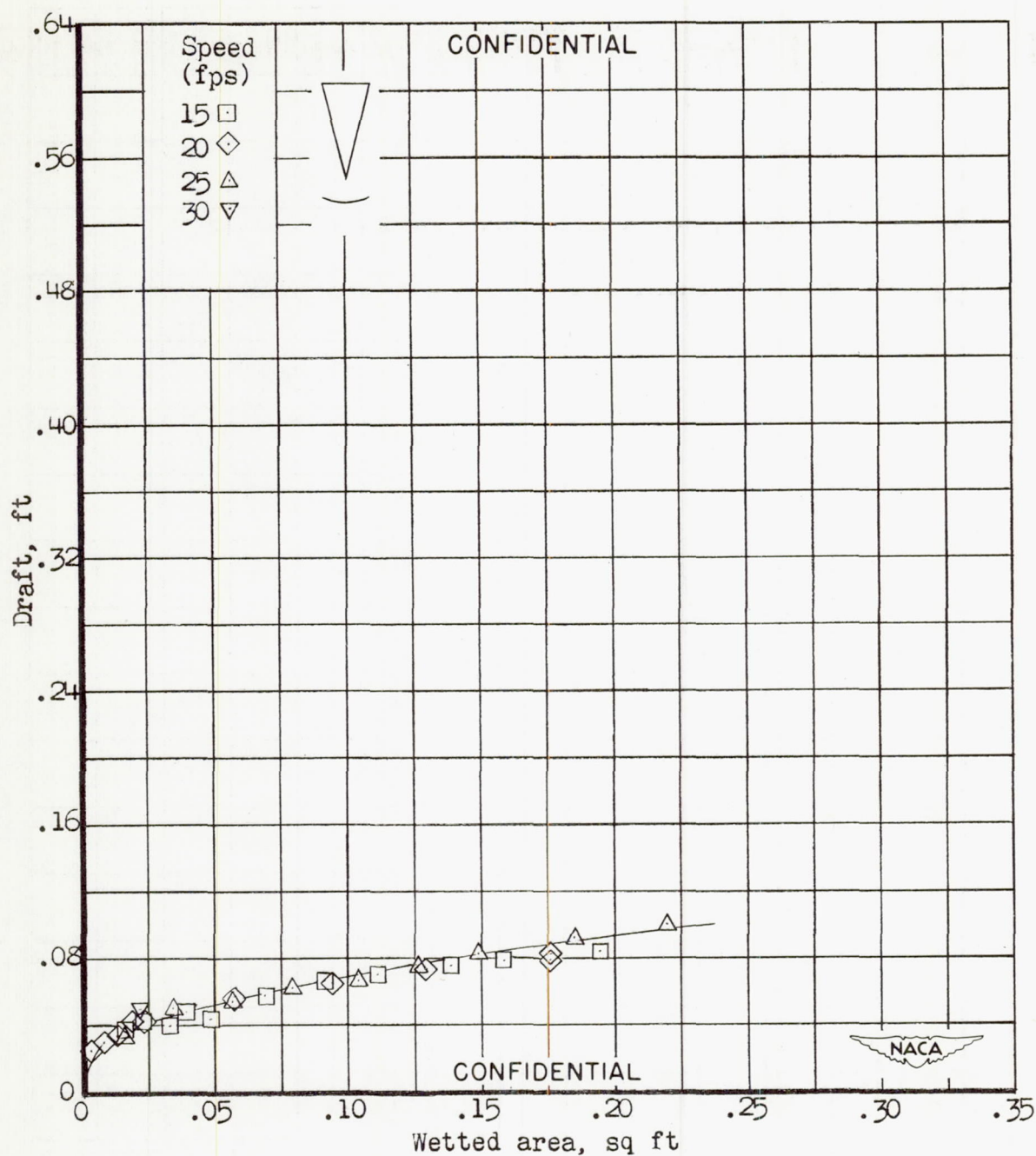
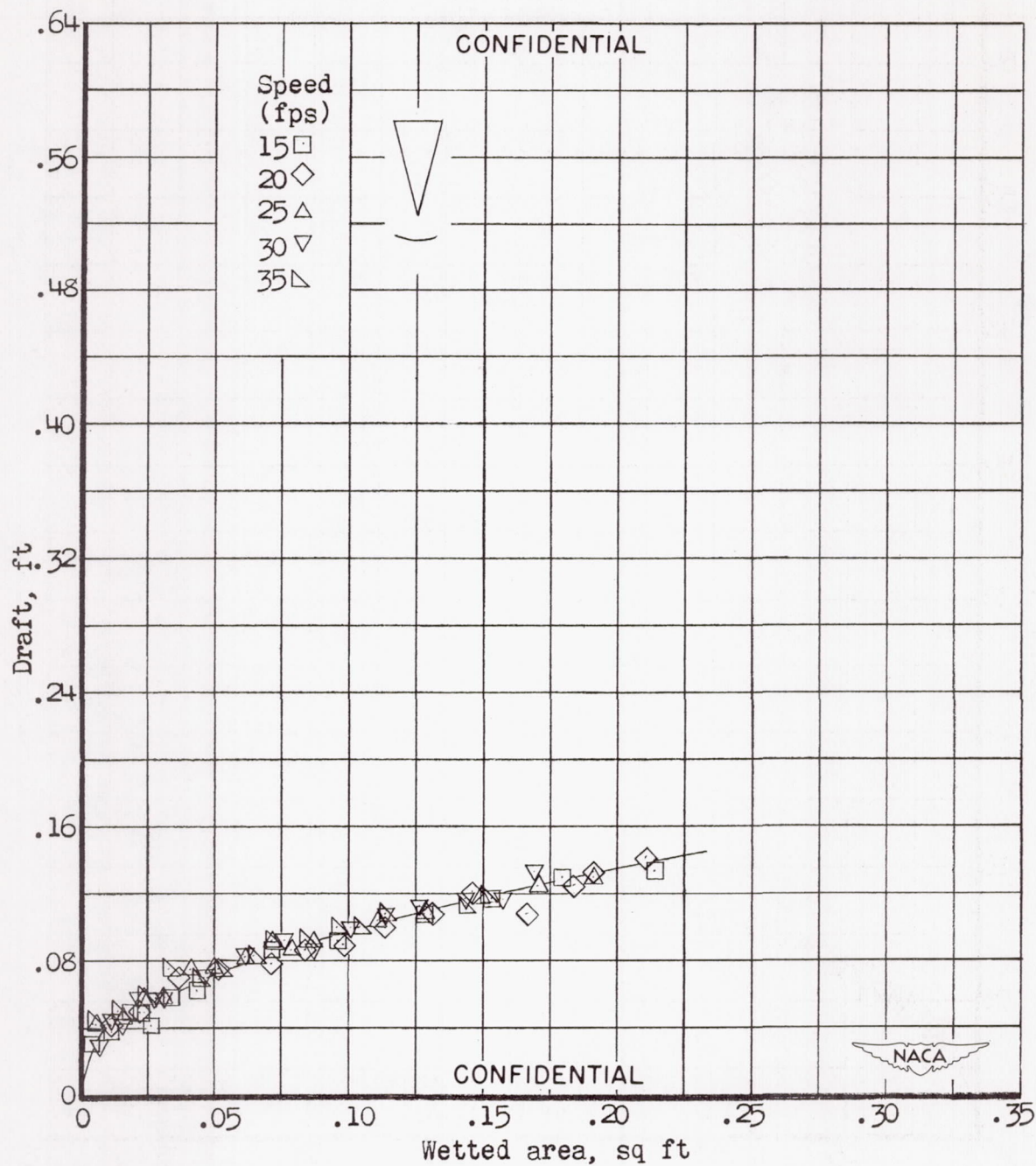


Figure 27.- Concluded.



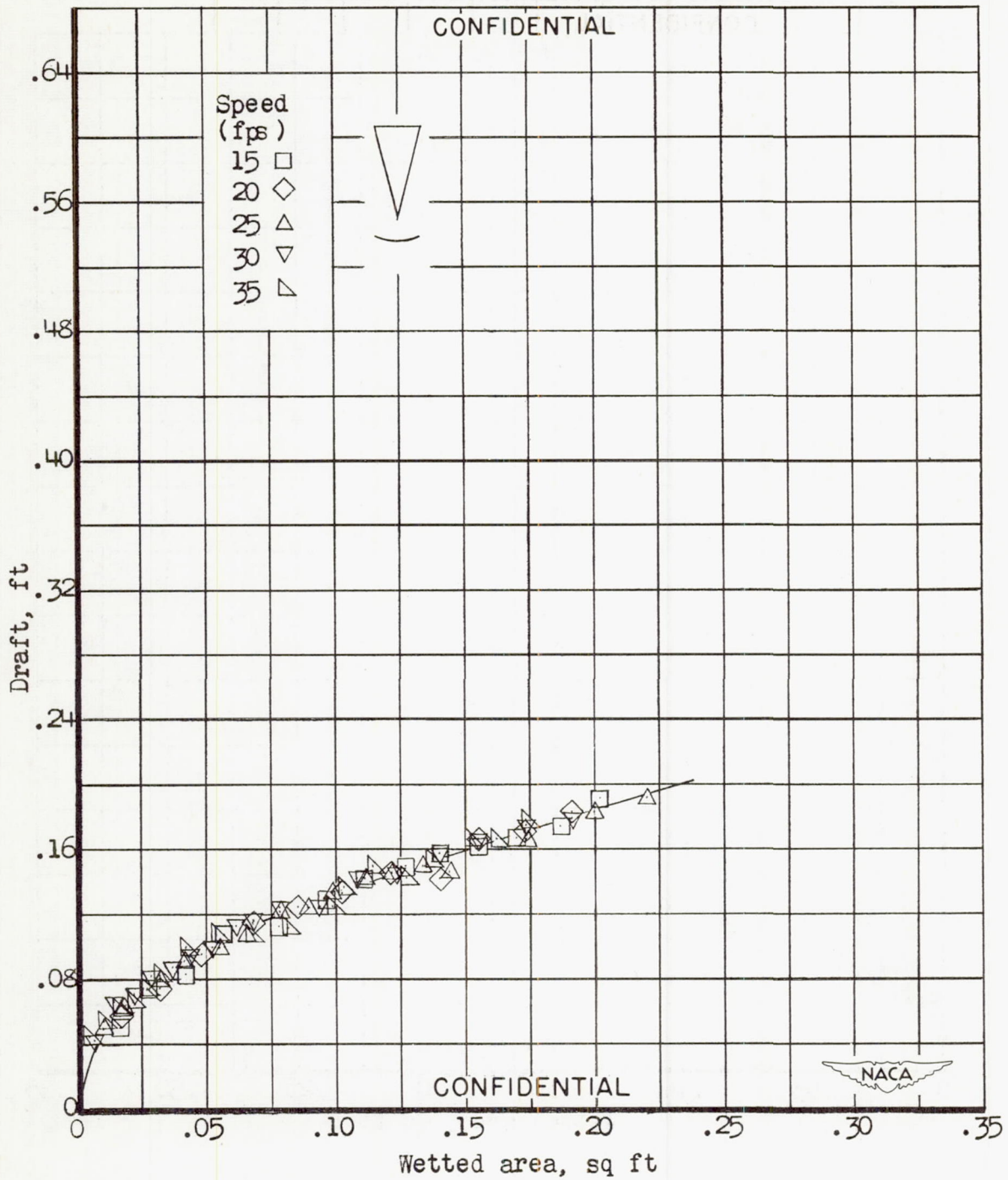
(a) $\tau = 40^\circ$.

Figure 28.- Variation of draft with wetted area. Model 250F.



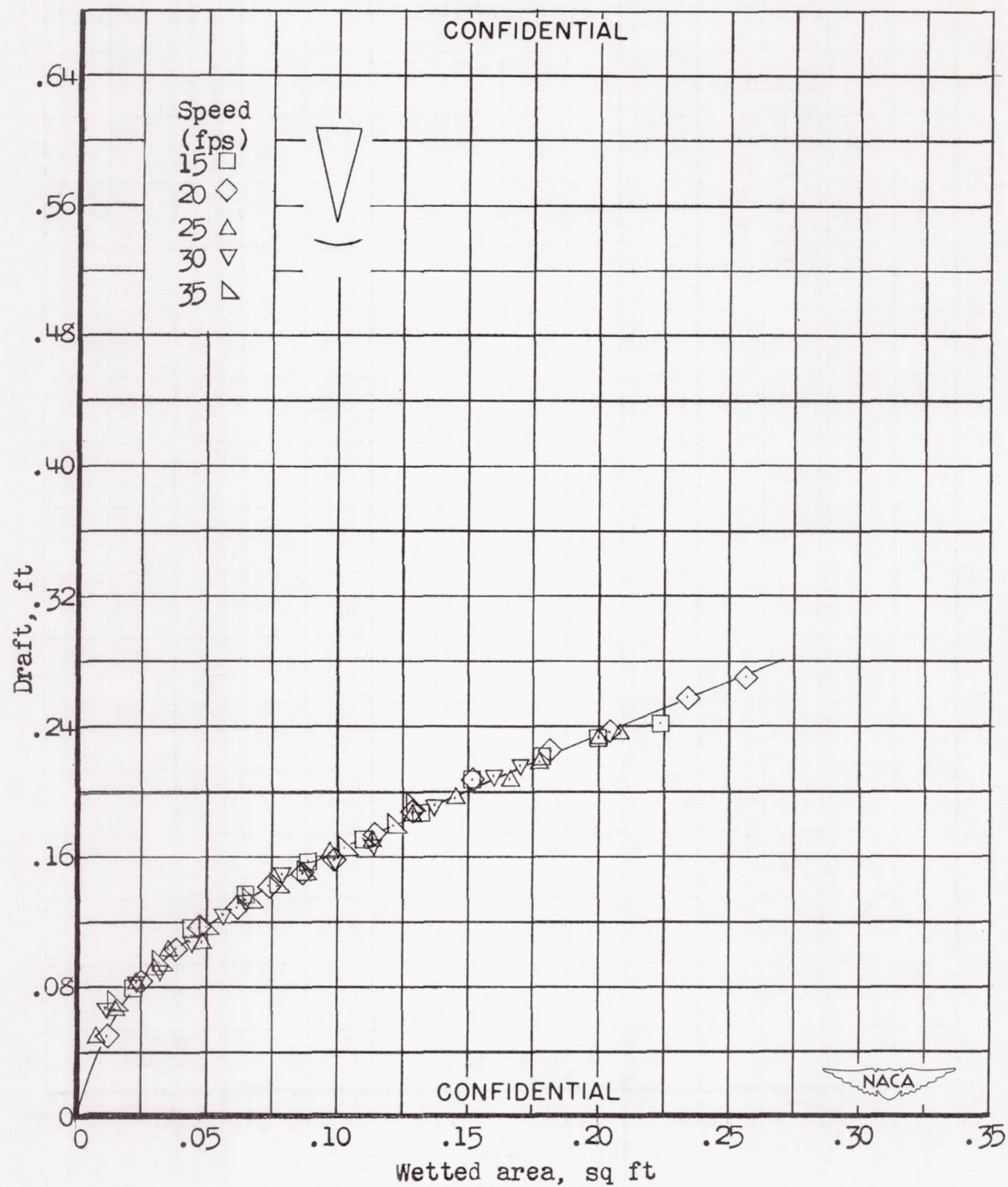
(b) $\tau = 8^\circ$.

Figure 28.- Continued.



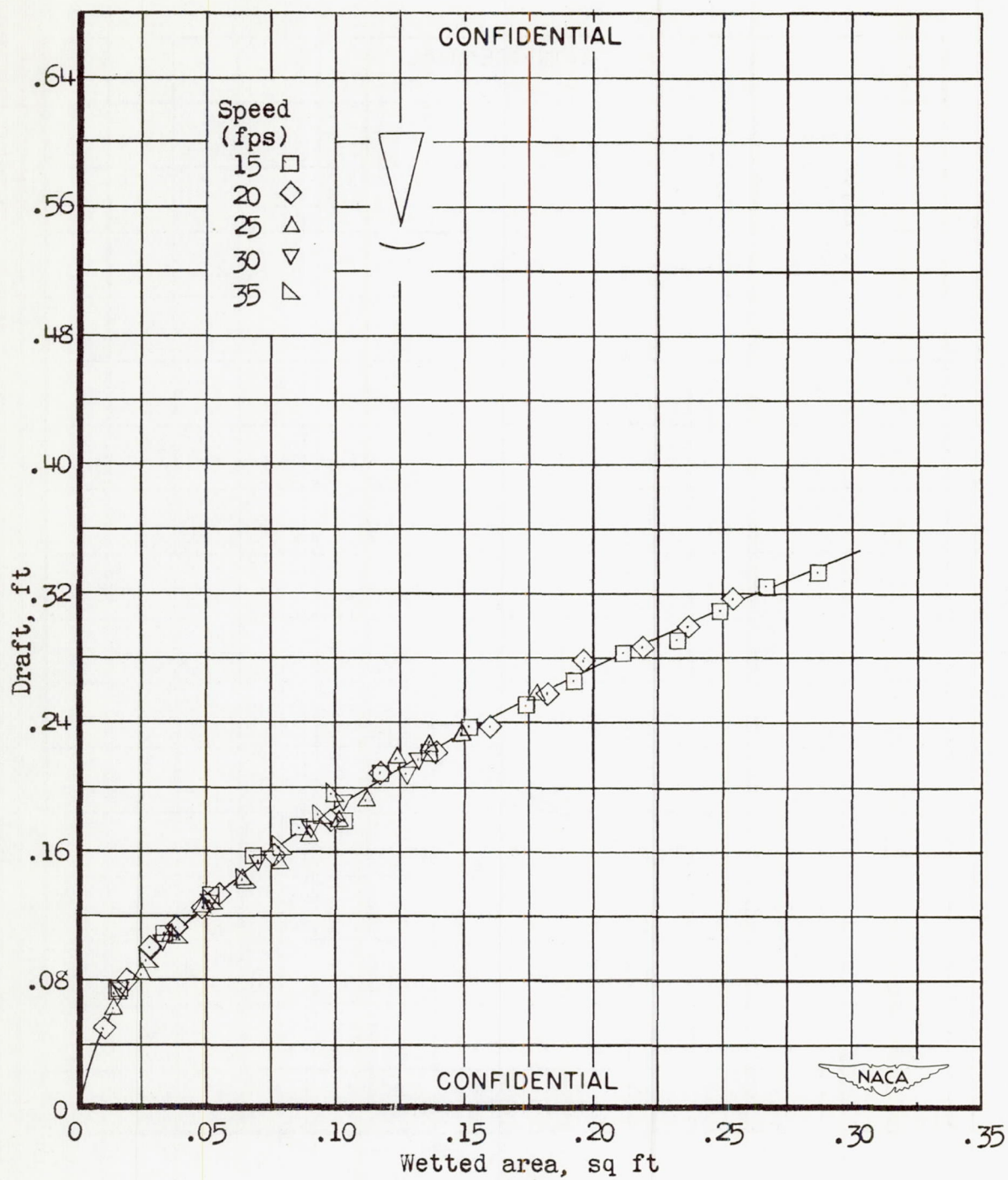
(c) $\tau = 12^\circ$.

Figure 28.- Continued.



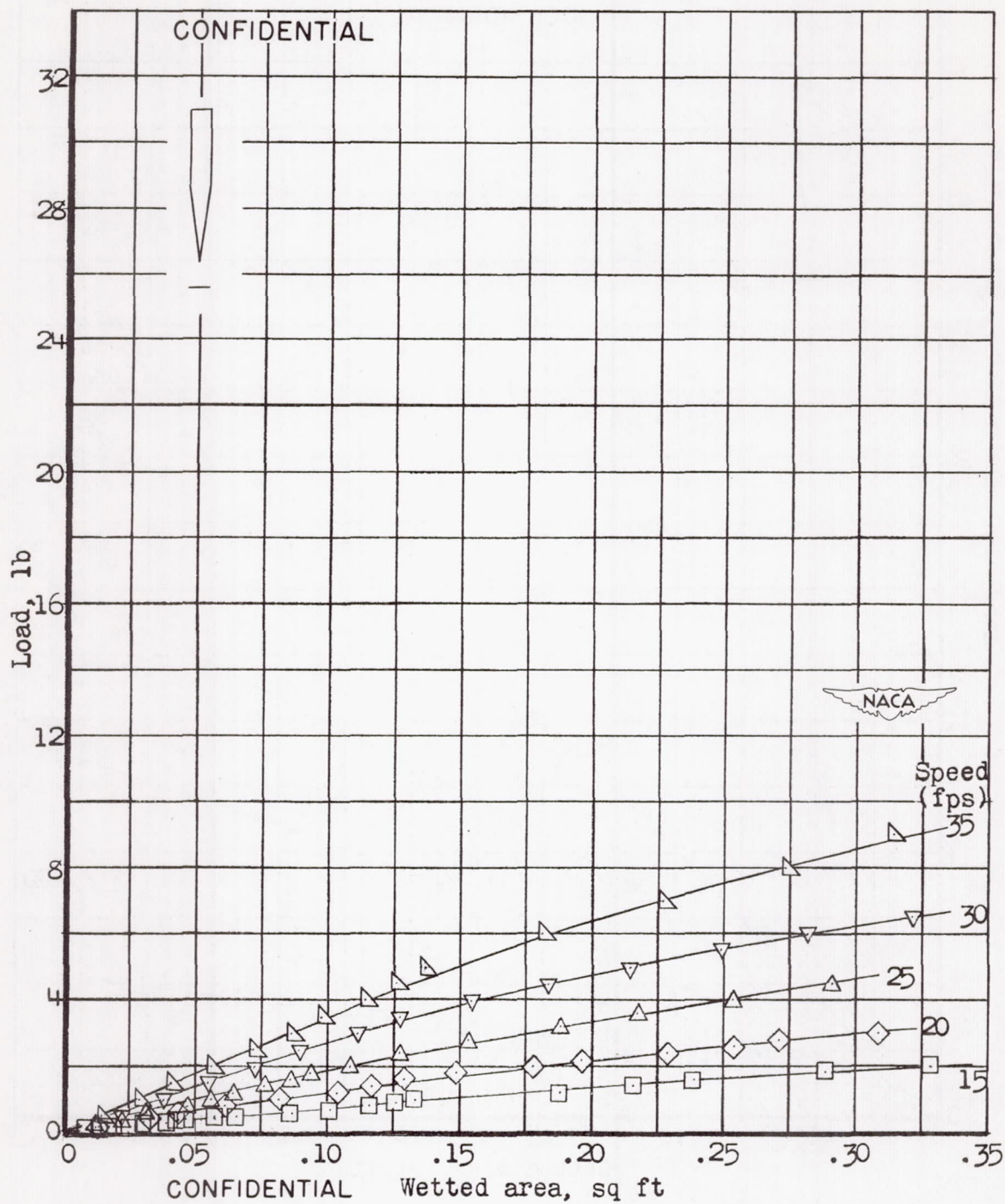
(d) $\tau = 16^\circ$.

Figure 28.- Continued.



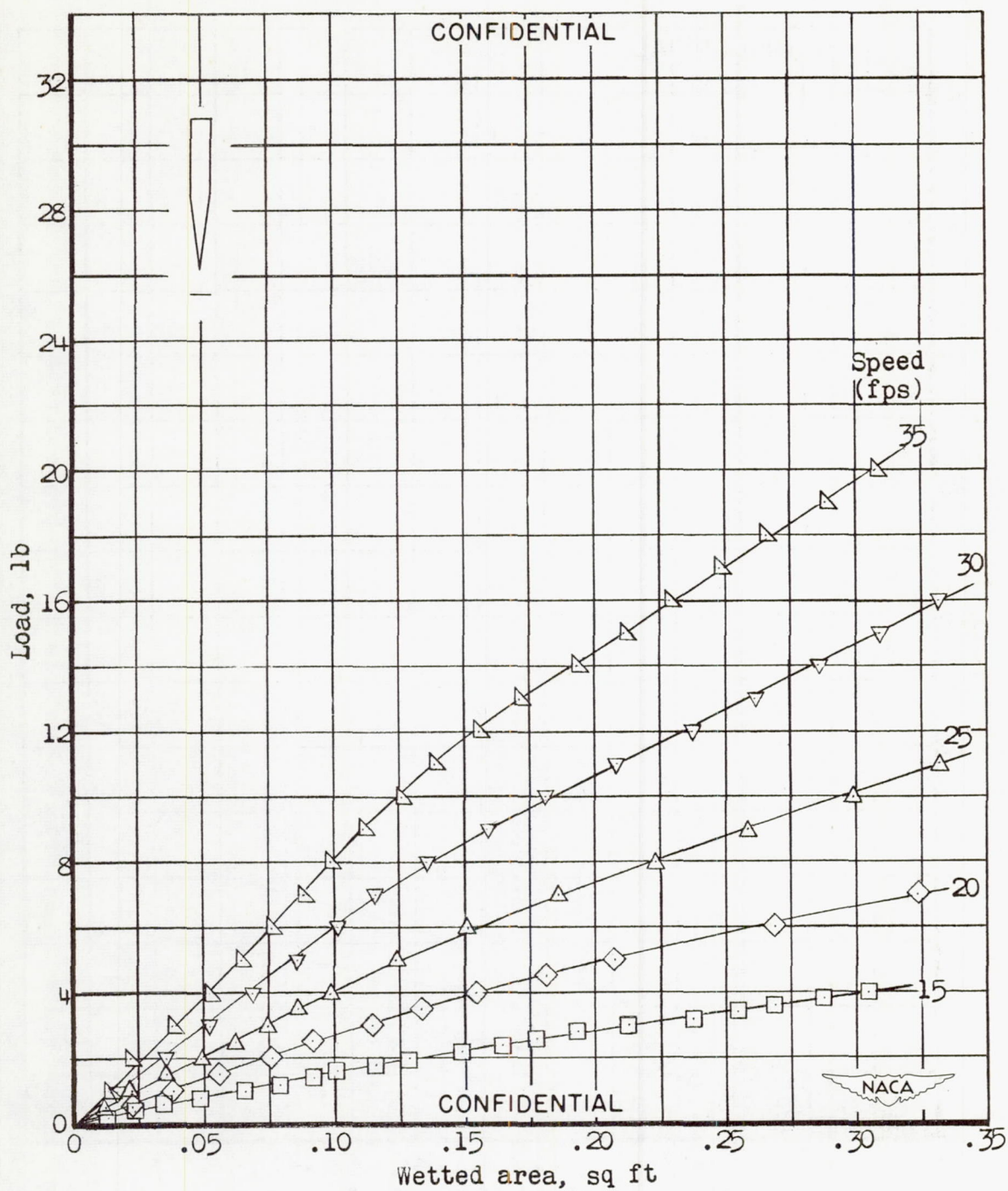
(e) $\tau = 20^\circ$.

Figure 28.-- Concluded.



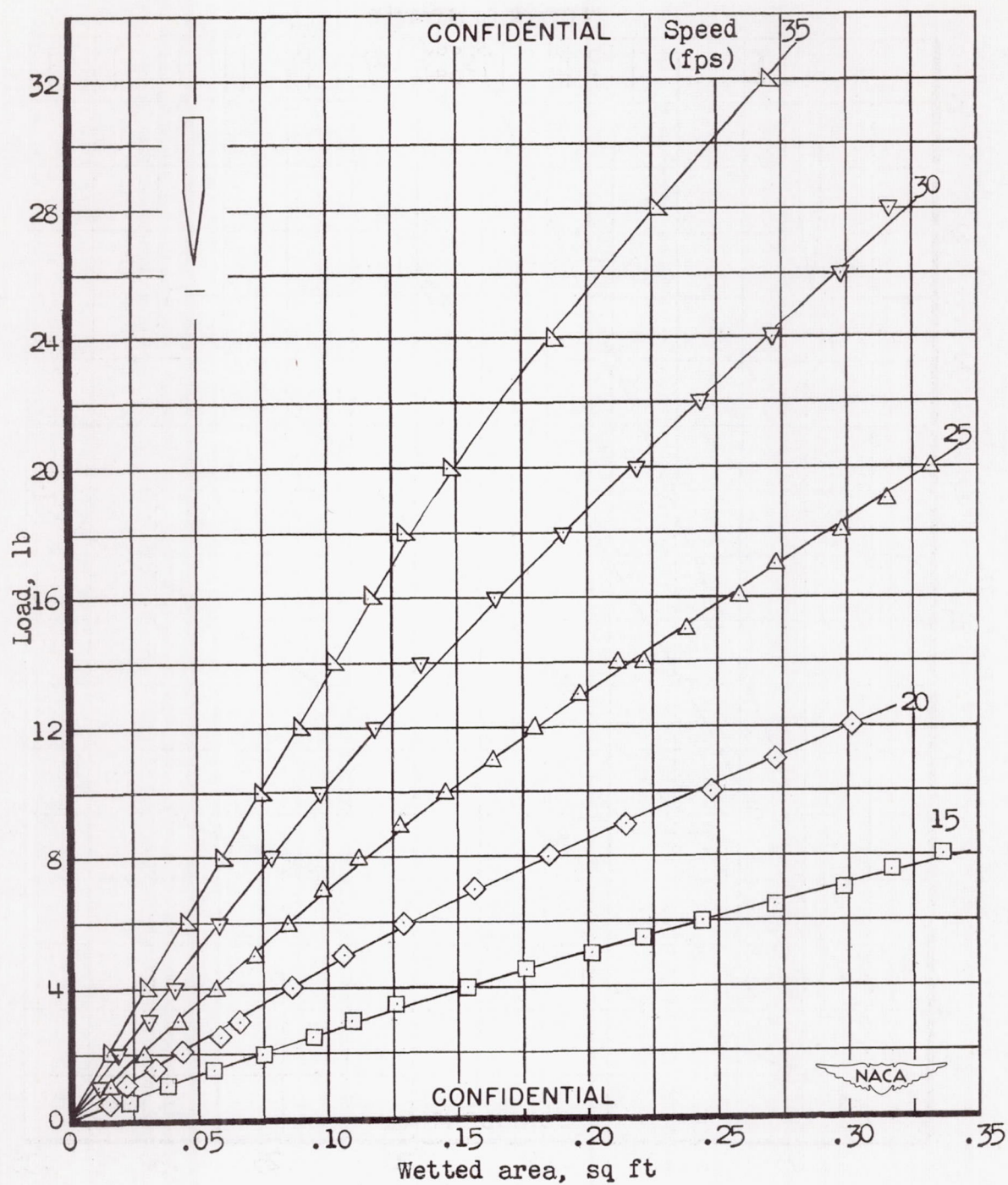
(a) $\tau = 4^\circ$.

Figure 29.- Variation of load with wetted area. Model 250G.



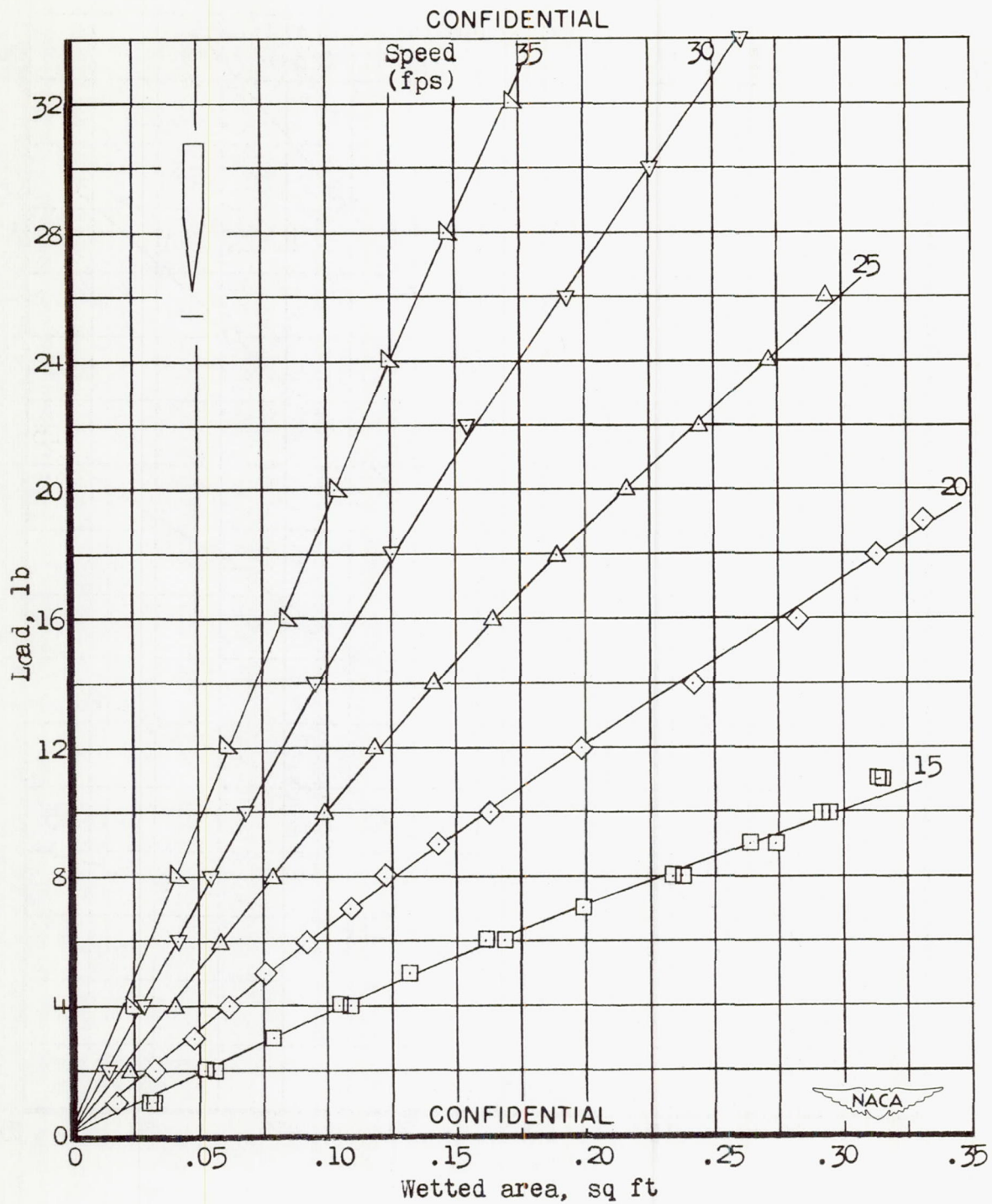
(b) $\tau = 8^\circ$.

Figure 29.- Continued.



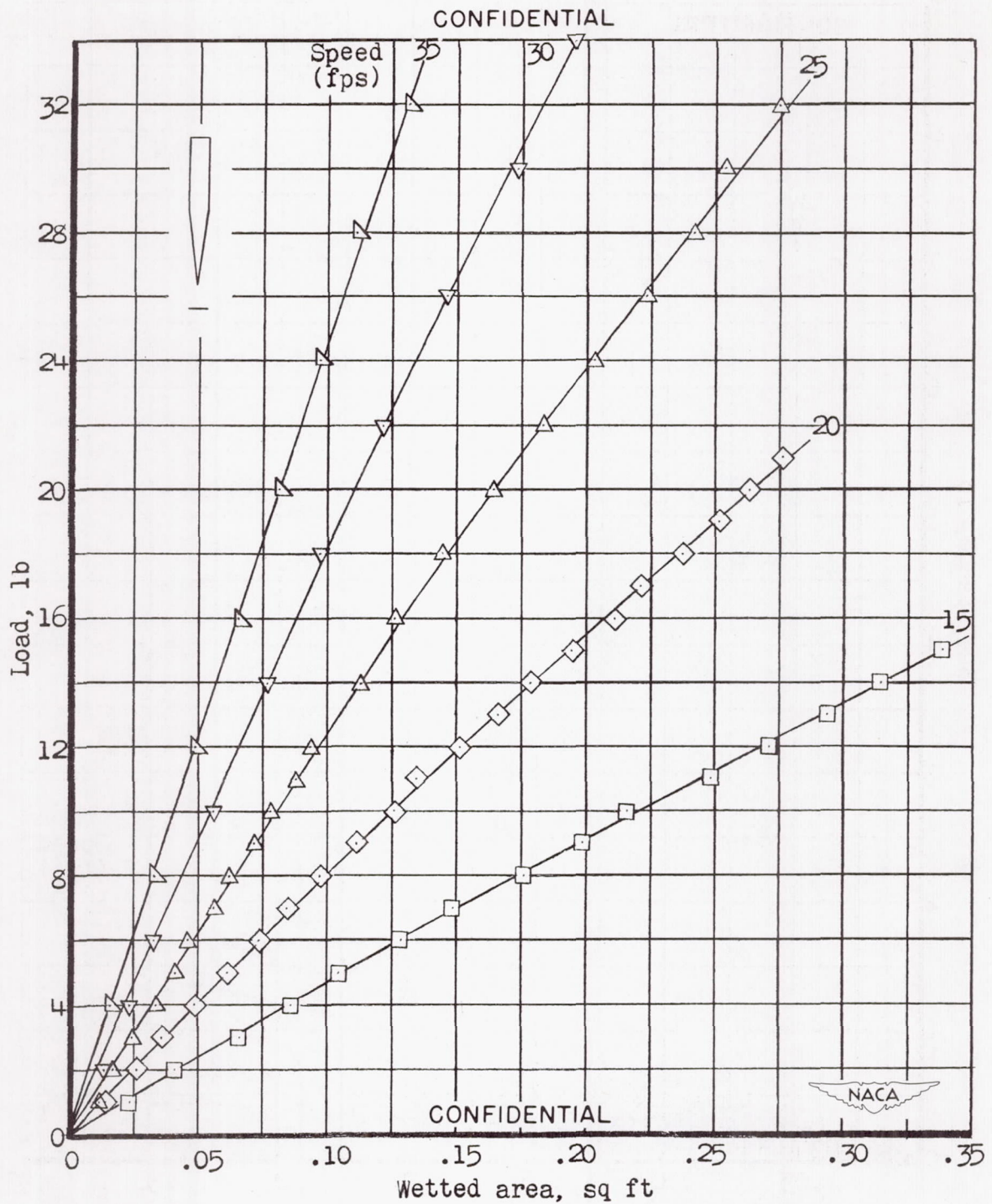
(c) $\tau = 12^\circ$.

Figure 29.- Continued.



(d) $\tau = 16^\circ$.

Figure 29.- Continued.



(e) $\tau = 20^\circ$.

Figure 29.- Concluded.

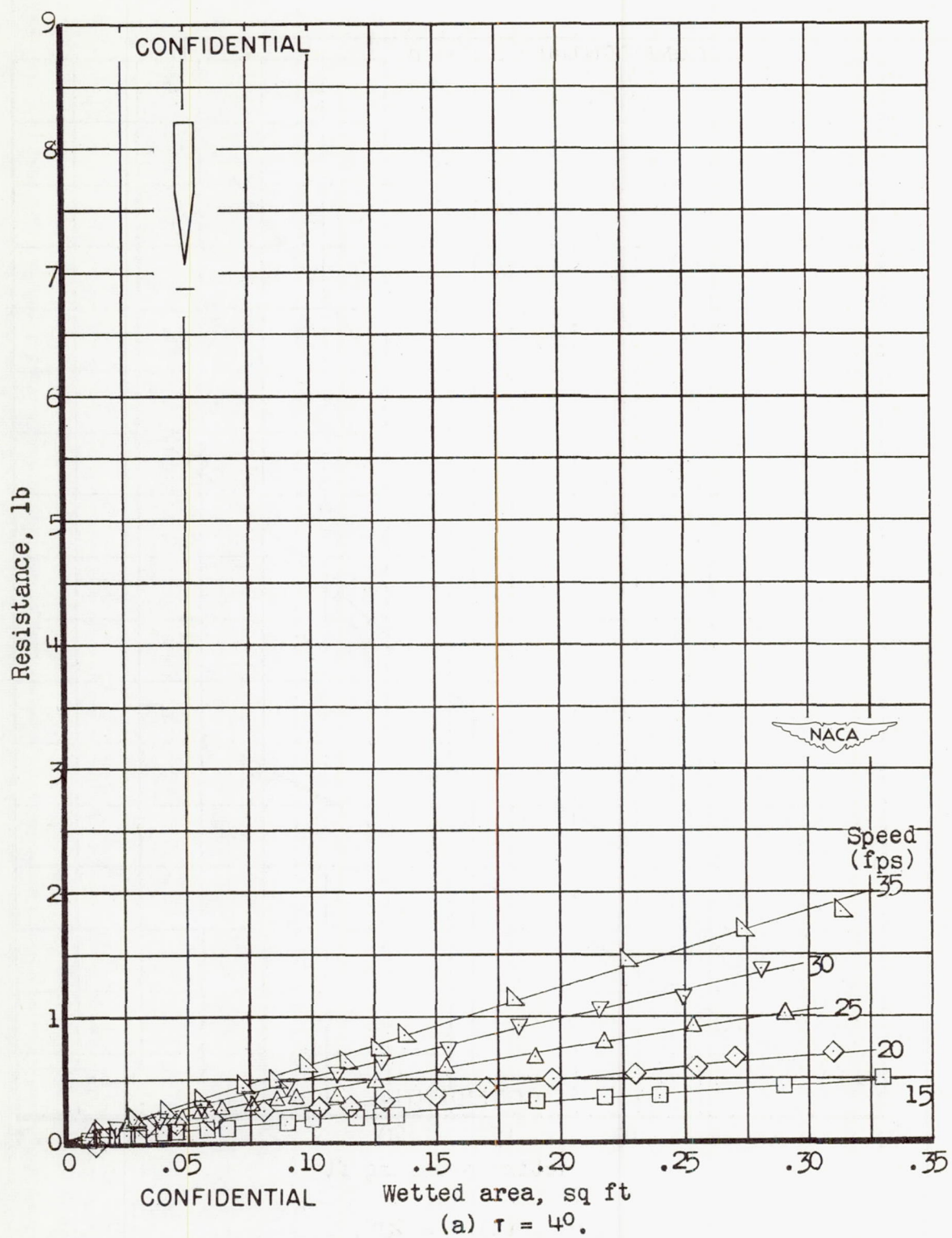
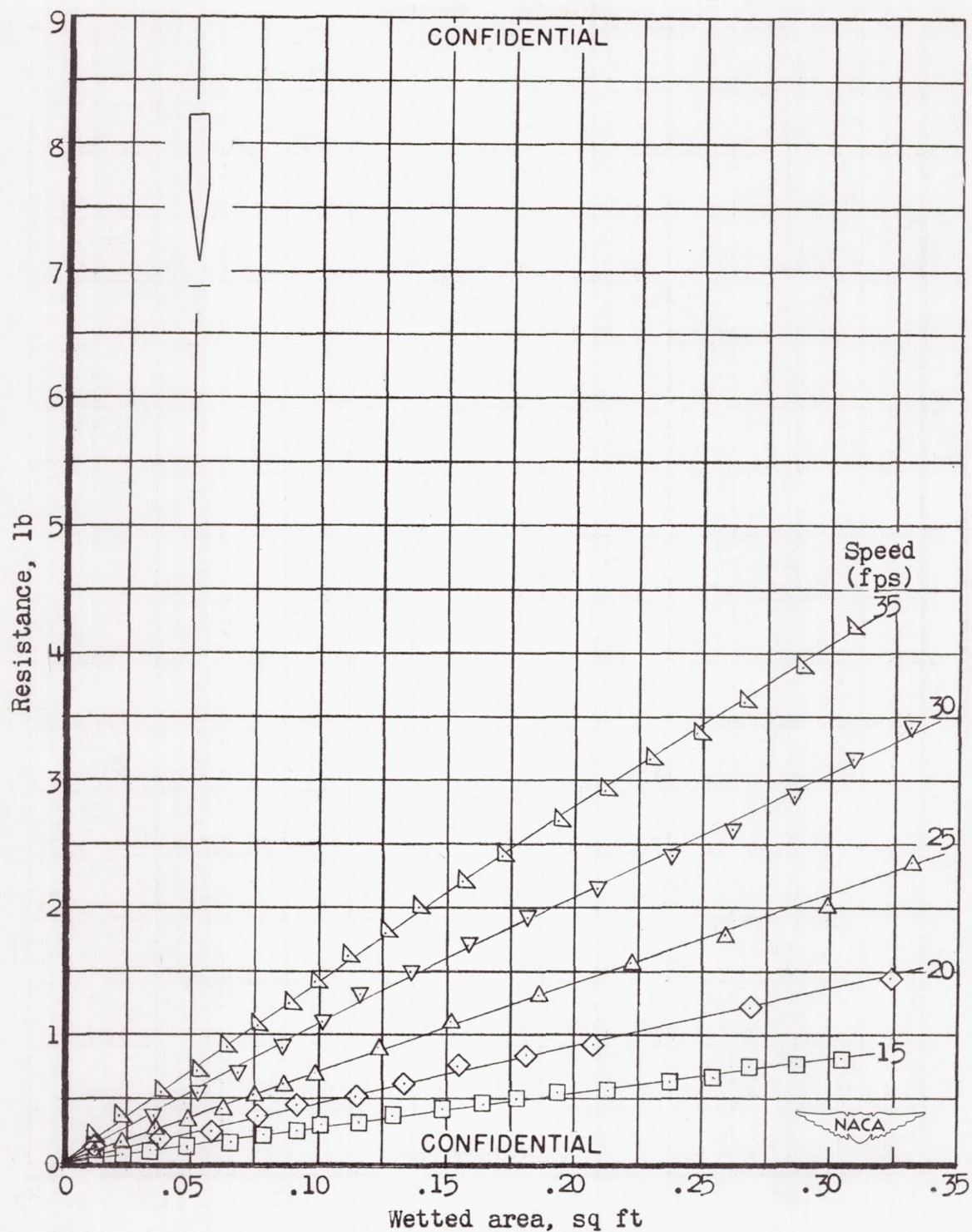
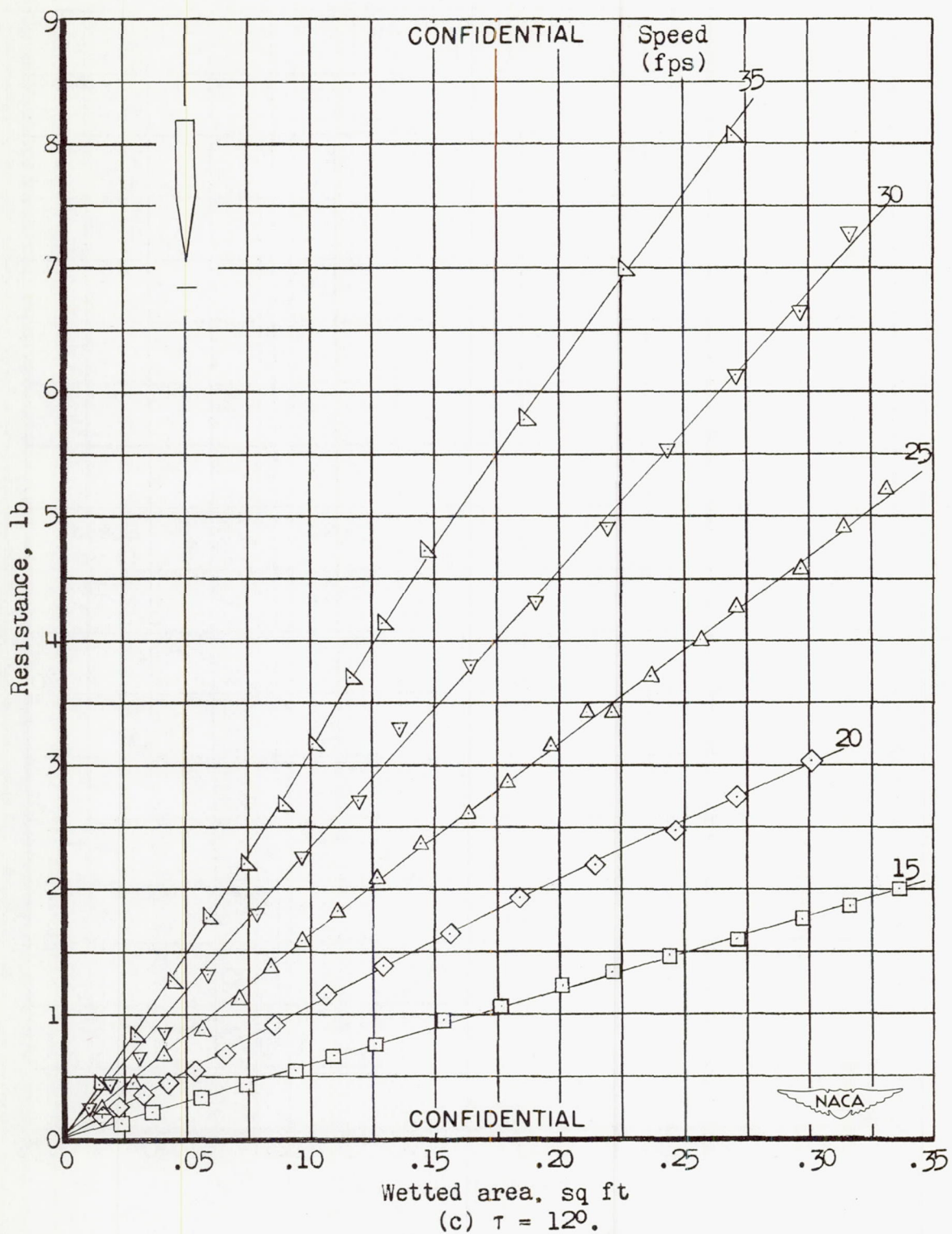


Figure 30.- Variation of resistance with wetted area. Model 250G.



(b) $\tau = 8^\circ$.

Figure 30.- Continued.



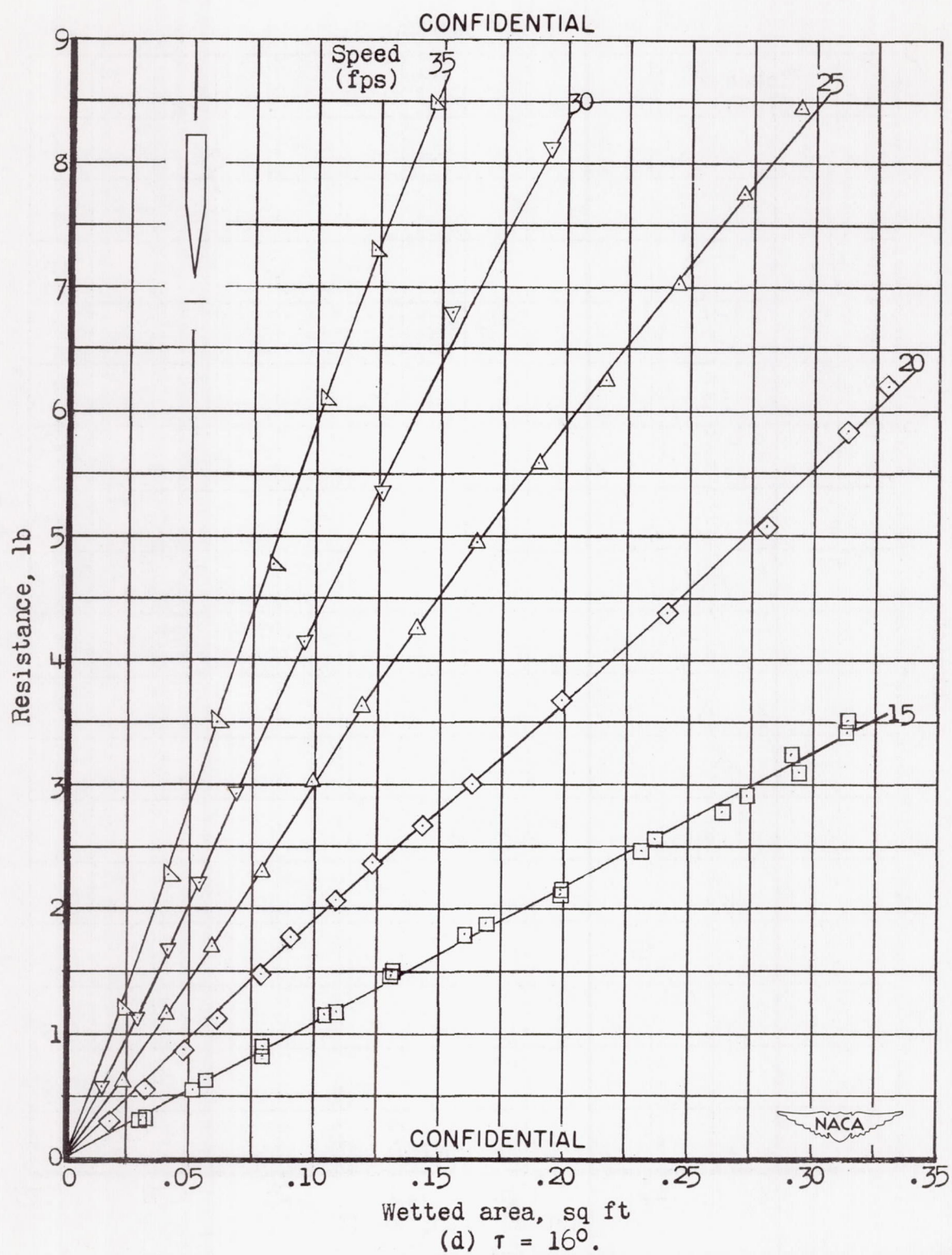
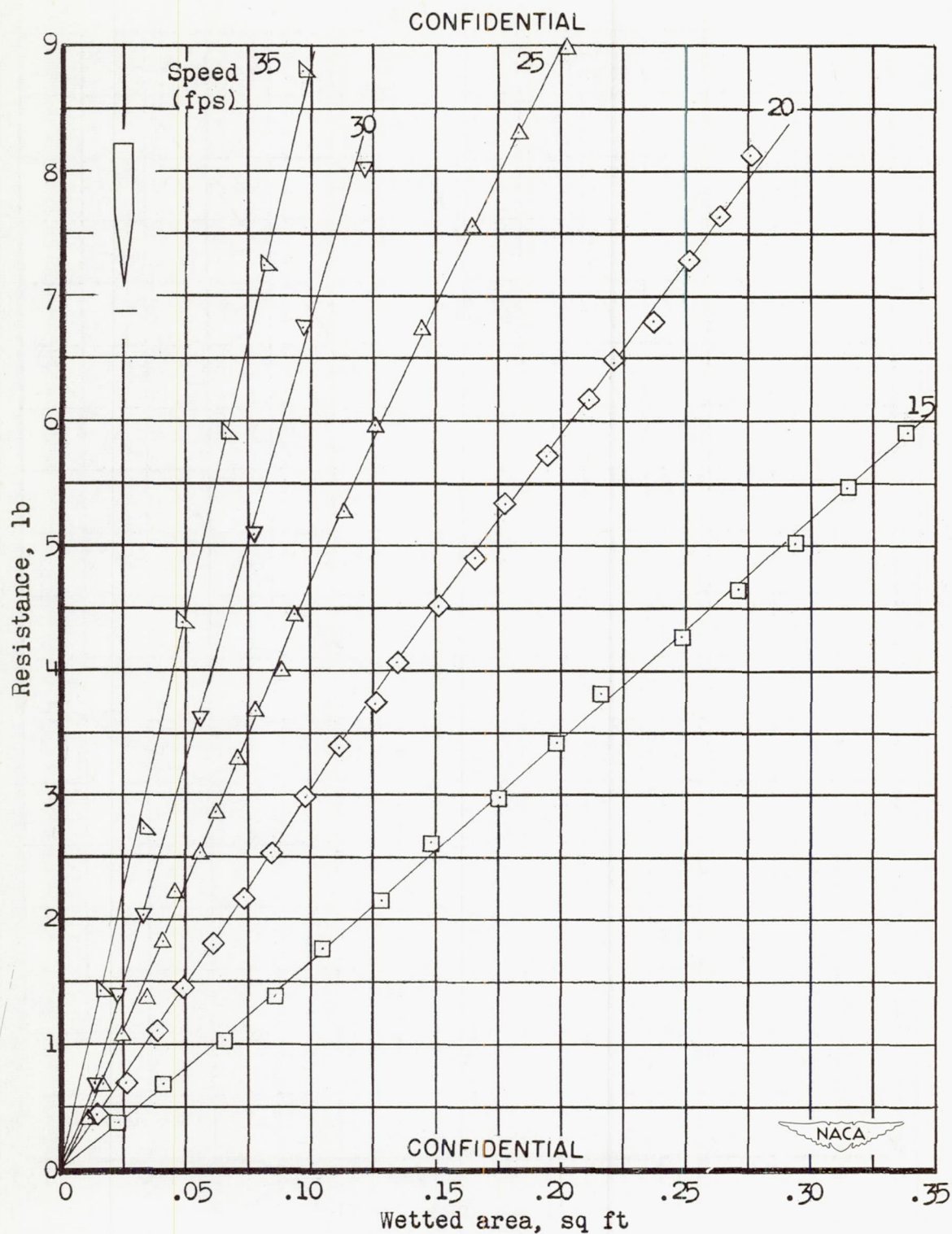


Figure 30.- Continued.



(e) $\tau = 20^\circ$.
Figure 30.-- Concluded.

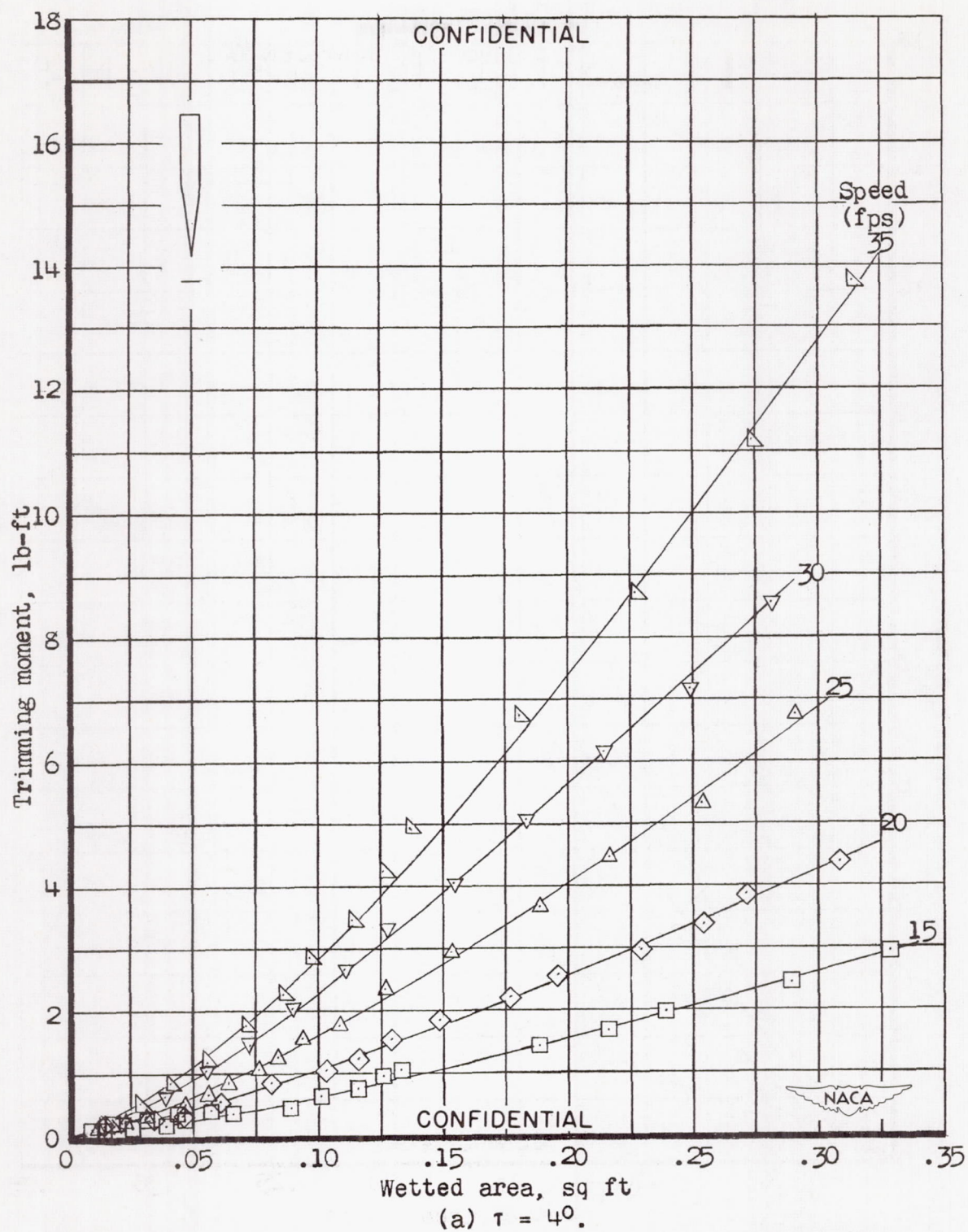
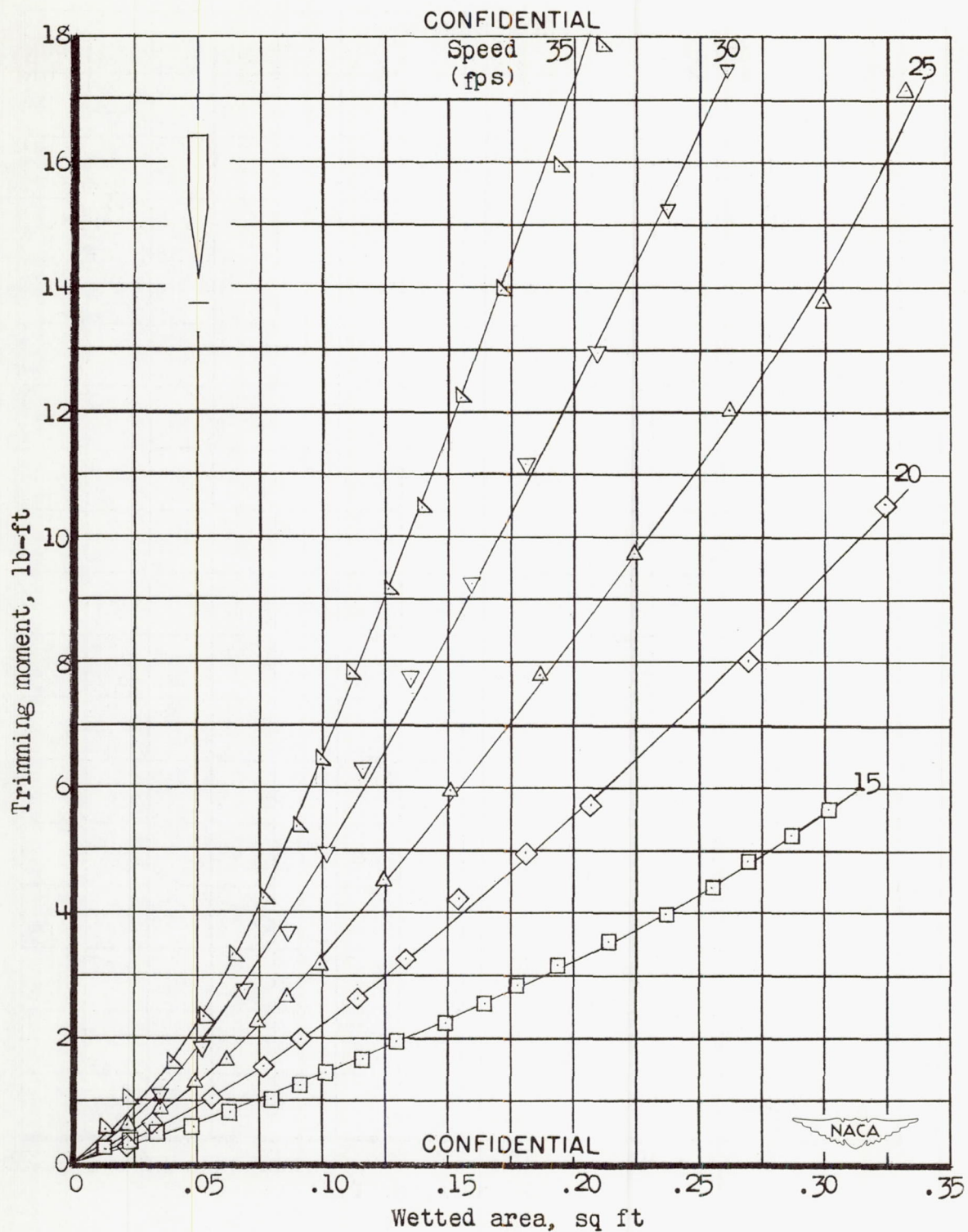


Figure 31.- Variation of moment with wetted area. Model 250G.



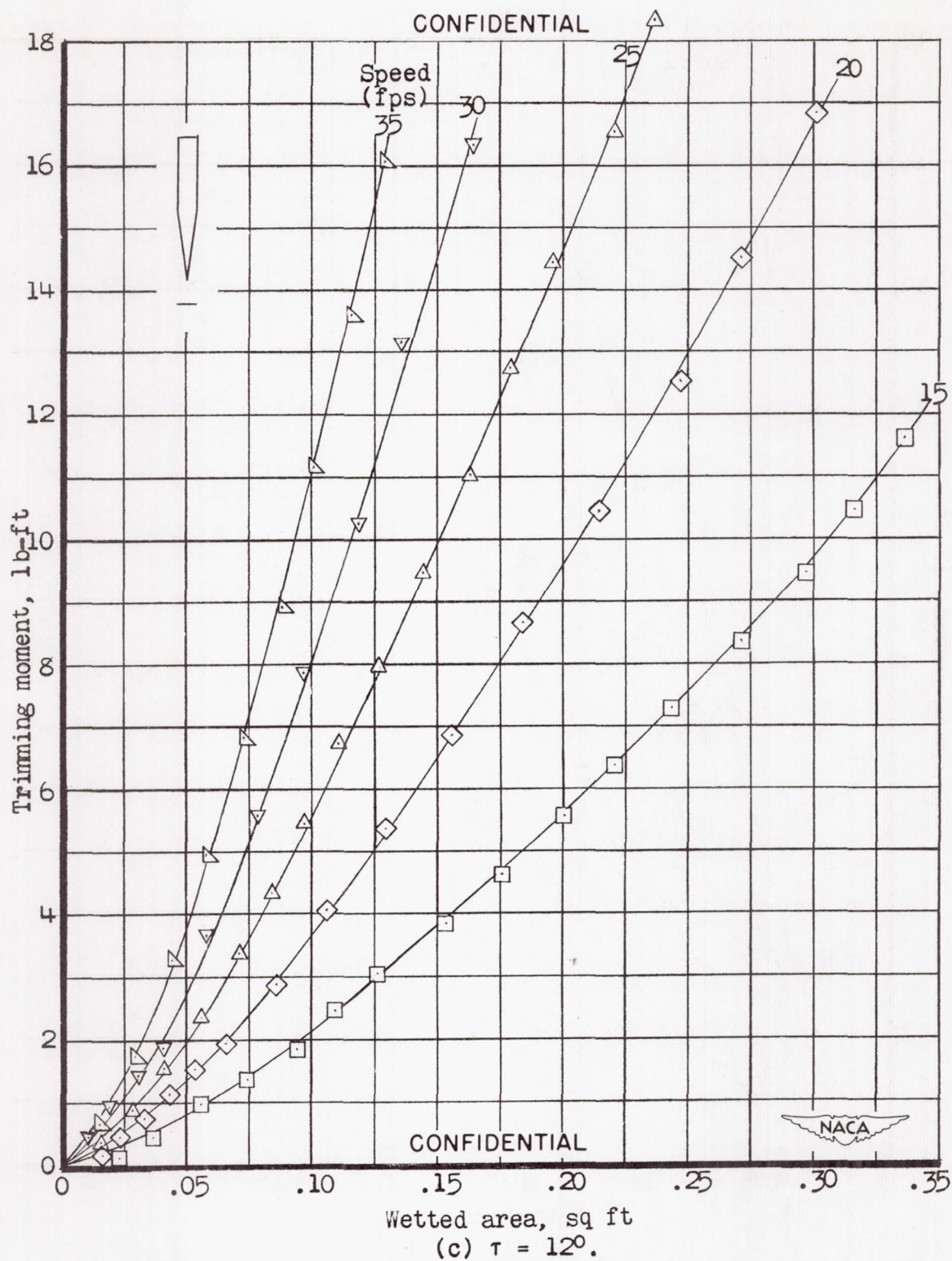
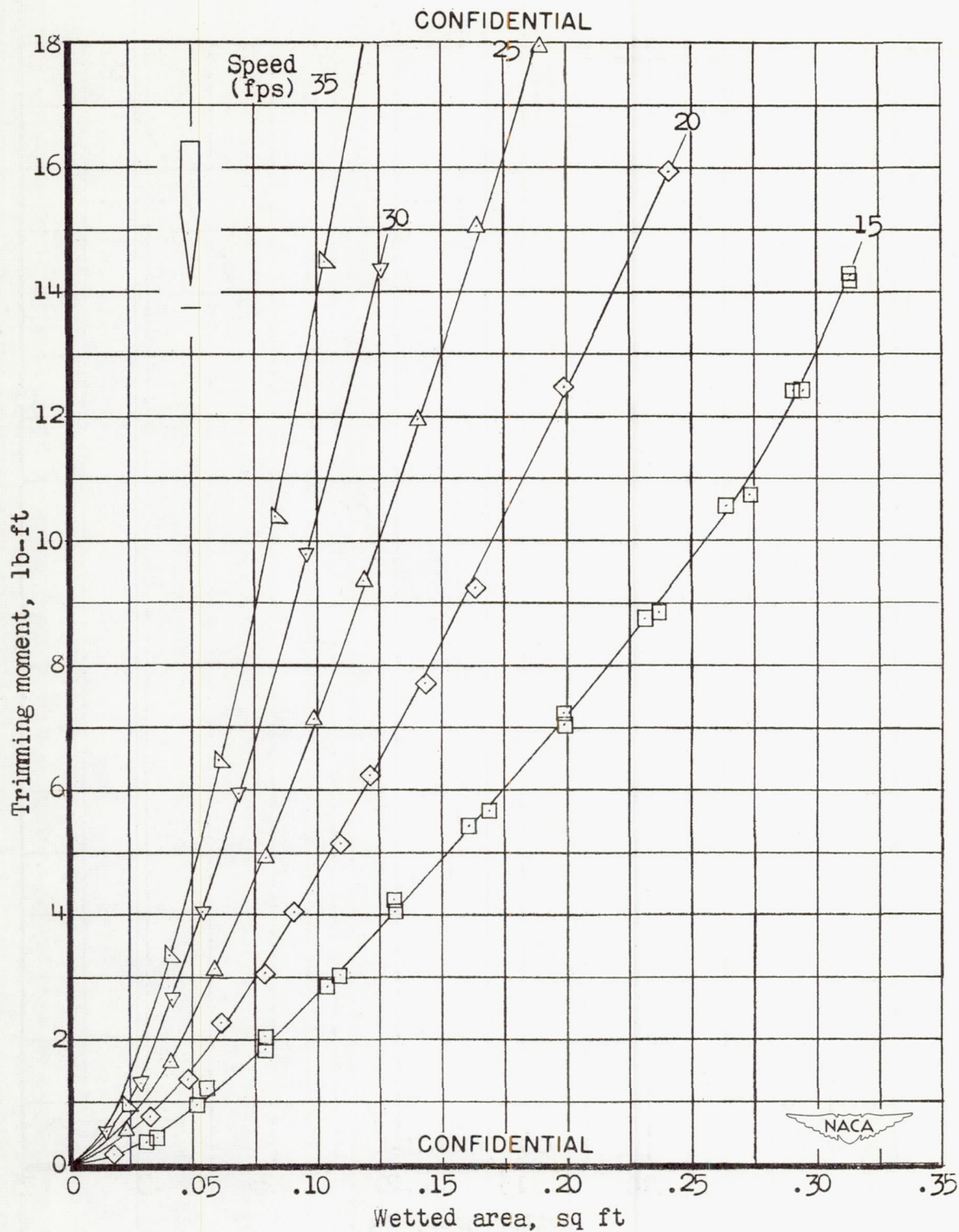


Figure 31.- Continued.



(d) $\tau = 16^\circ$.
Figure 31.- Continued.

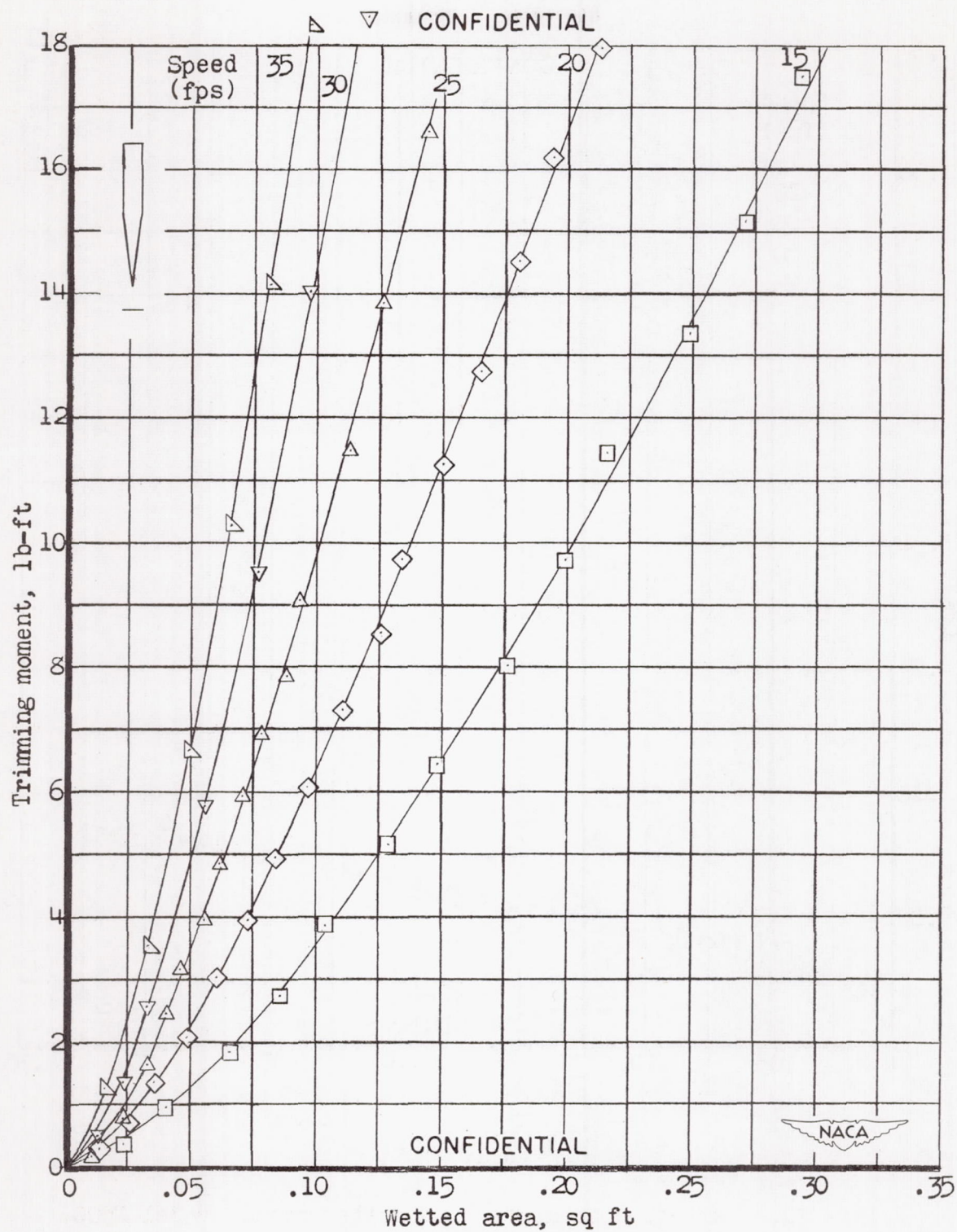
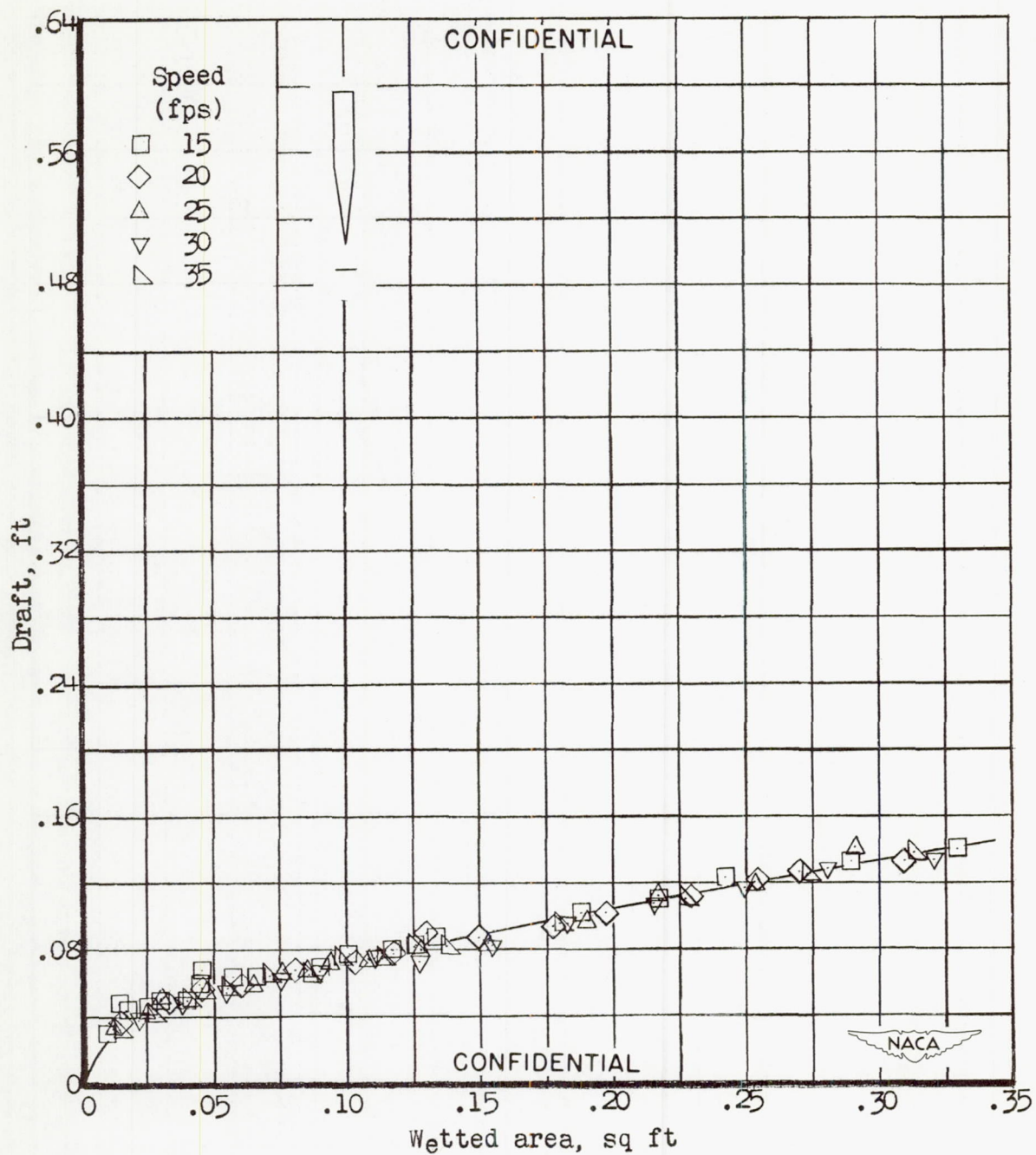
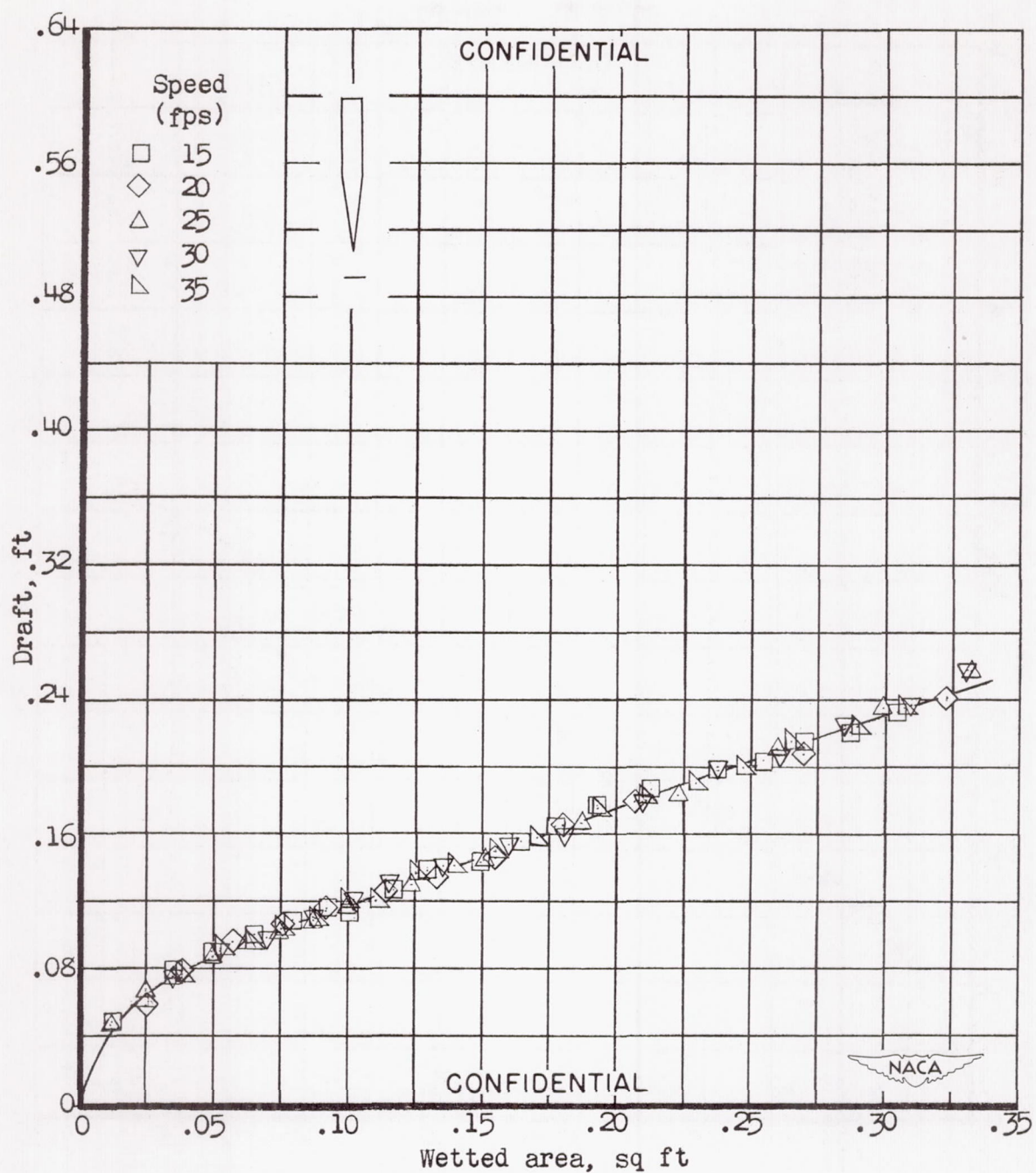
(e) $\tau = 20^\circ$.

Figure 31.- Concluded.



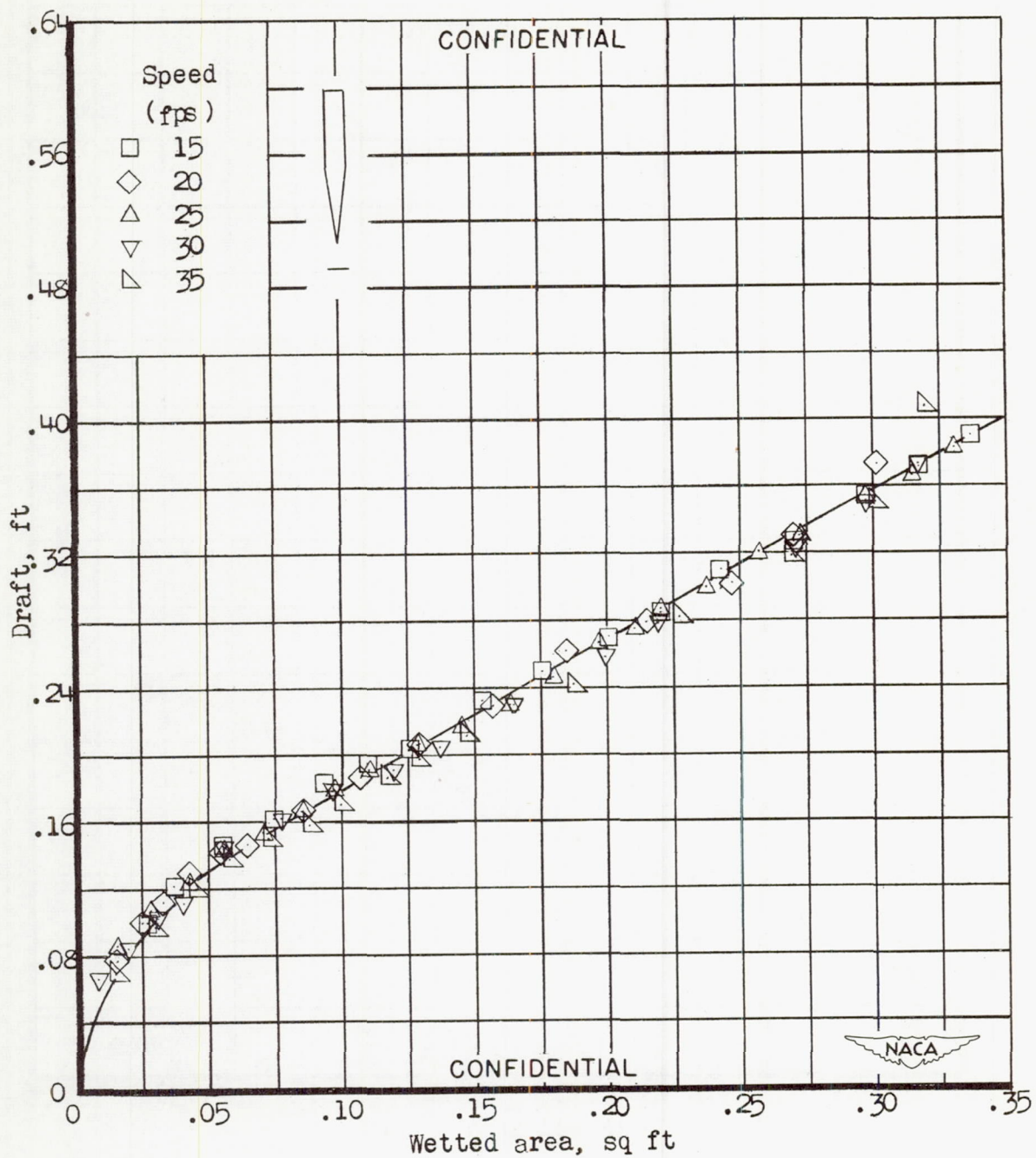
(a) $\tau = 4^\circ$.

Figure 32.- Variation of draft with wetted area. Model 250G.



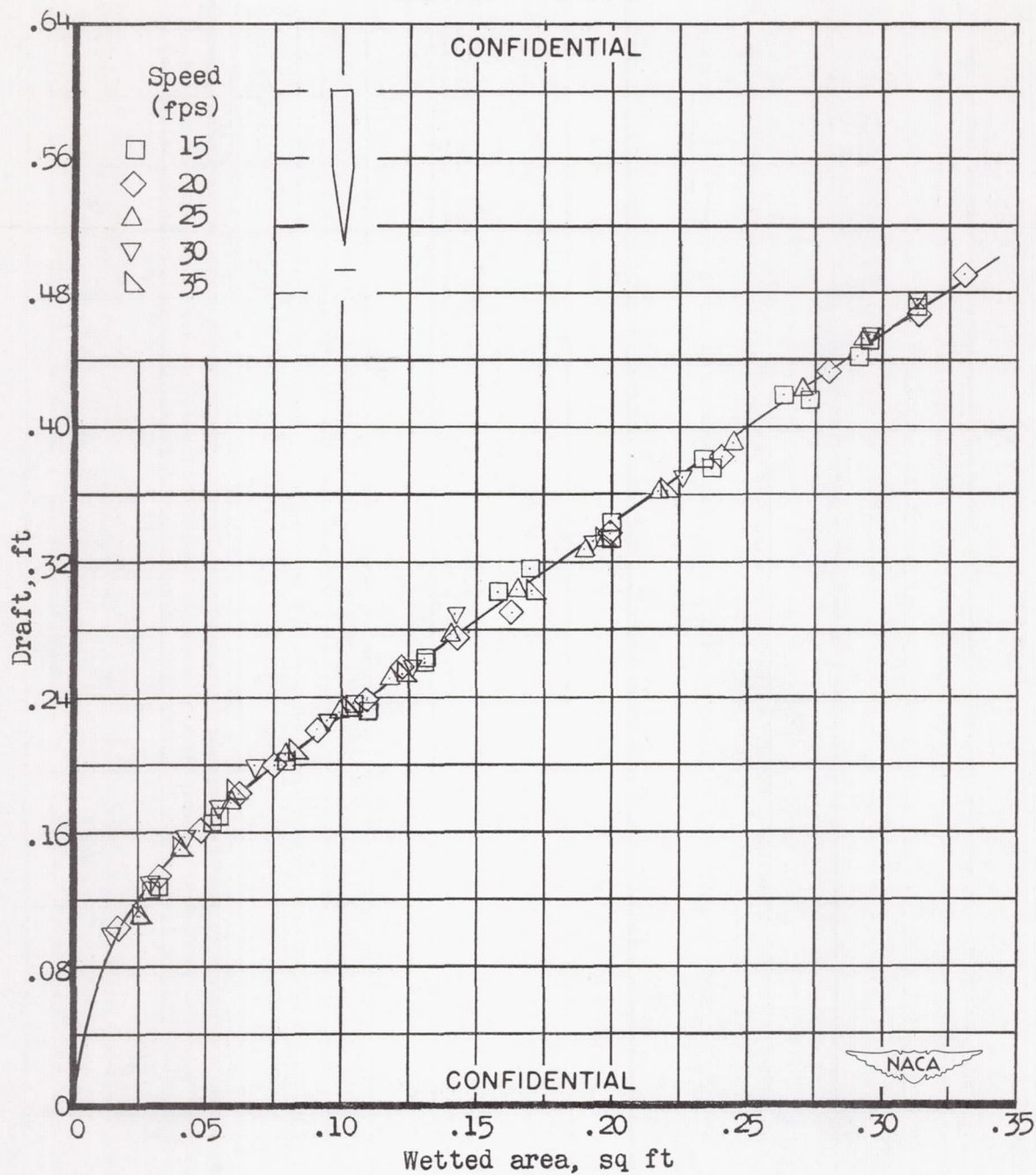
(b) $\tau = 8^\circ$.

Figure 32.- Continued.



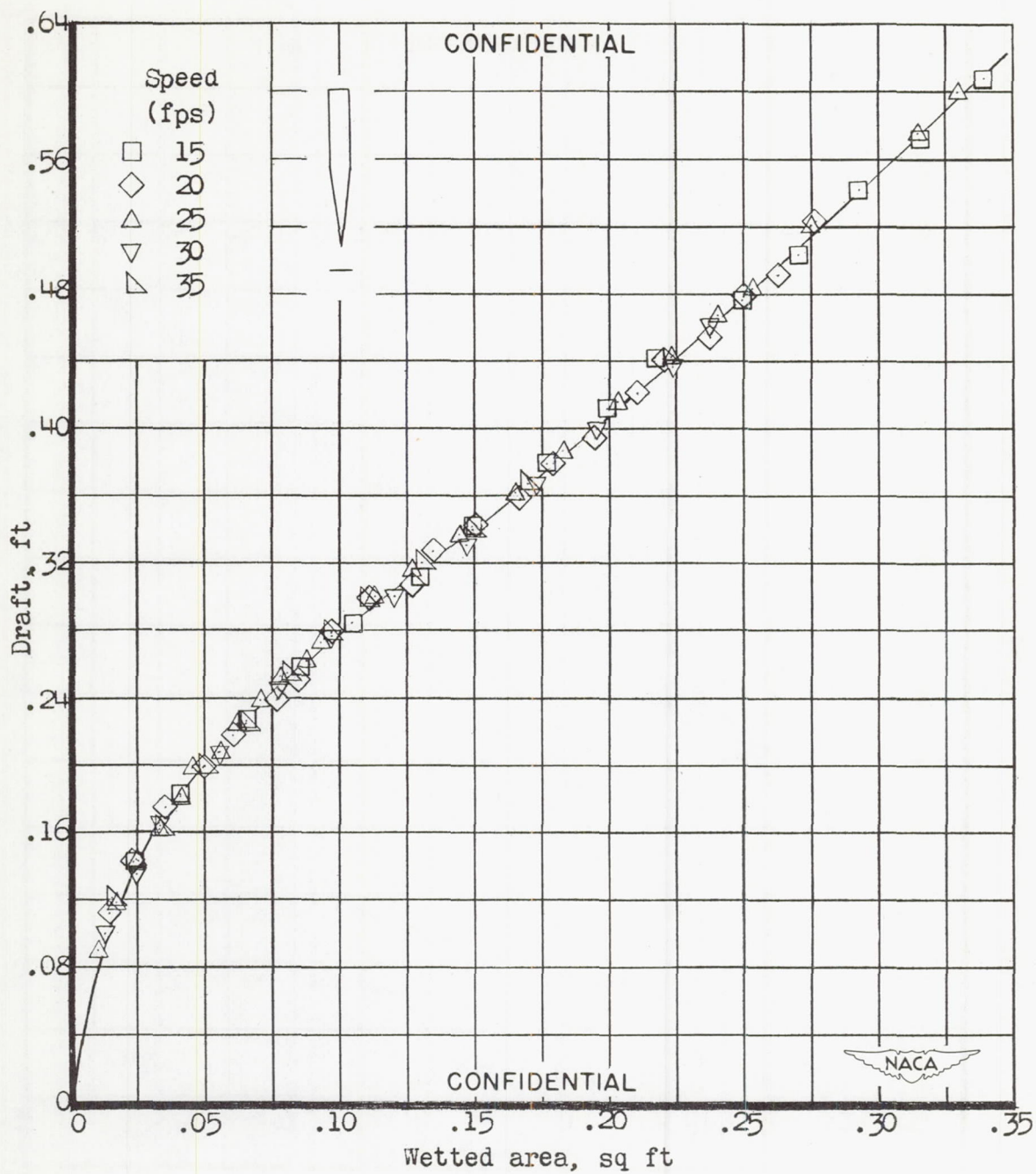
(c) $\tau = 12^\circ$.

Figure 32.- Continued.



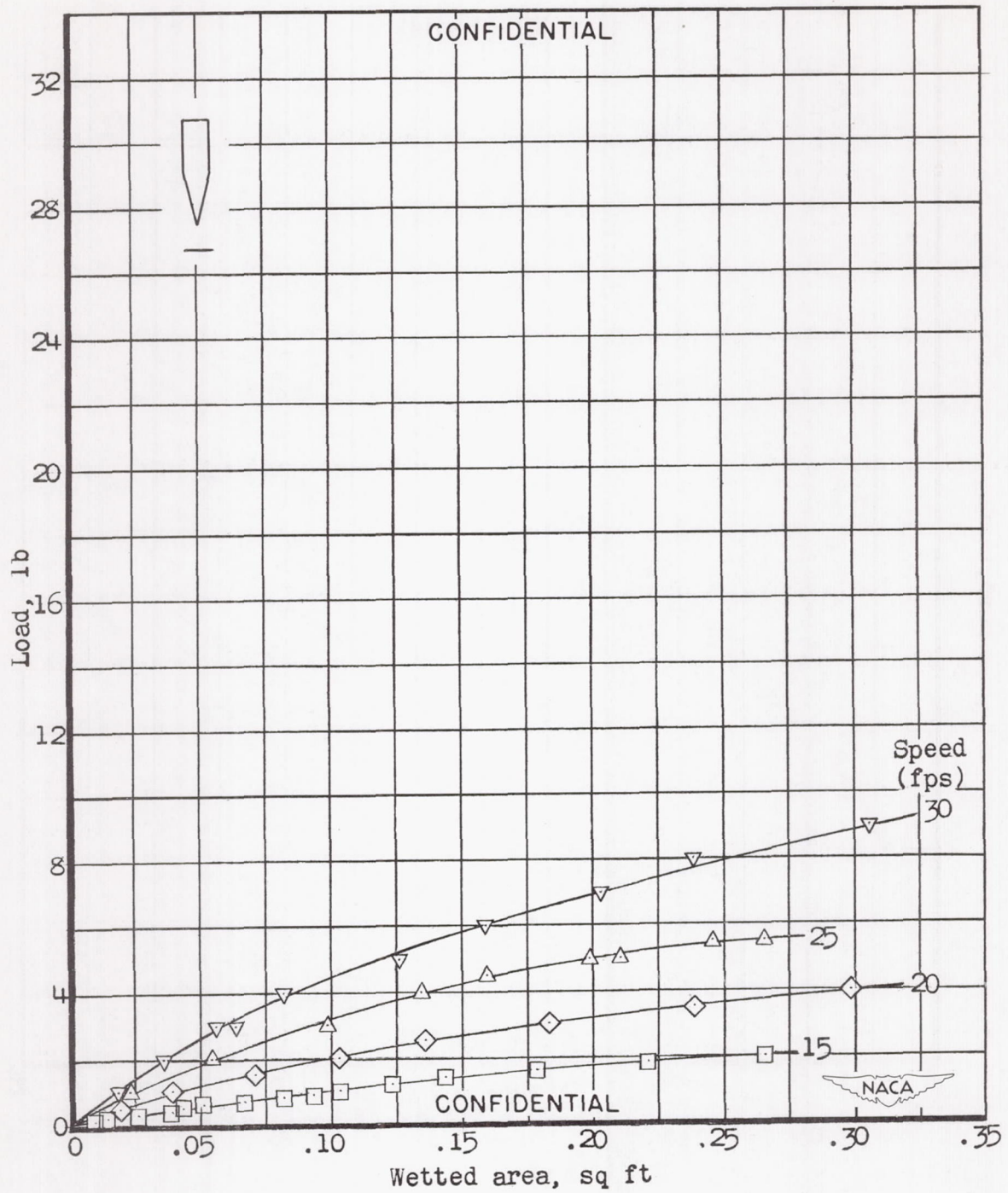
(d) $\tau = 16^\circ$.

Figure 32.- Continued.



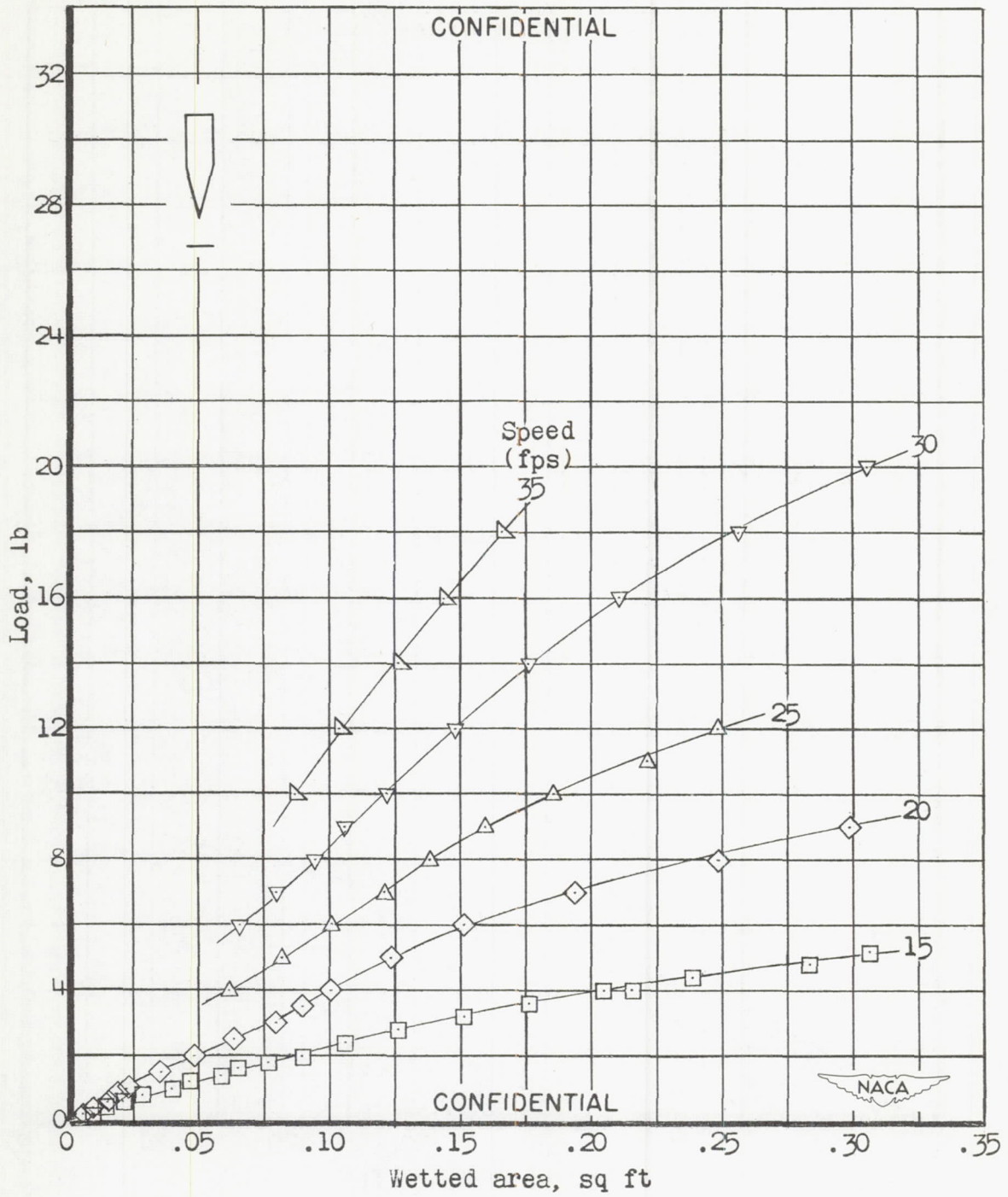
(e) $\tau = 20^\circ$.

Figure 32.- Concluded.



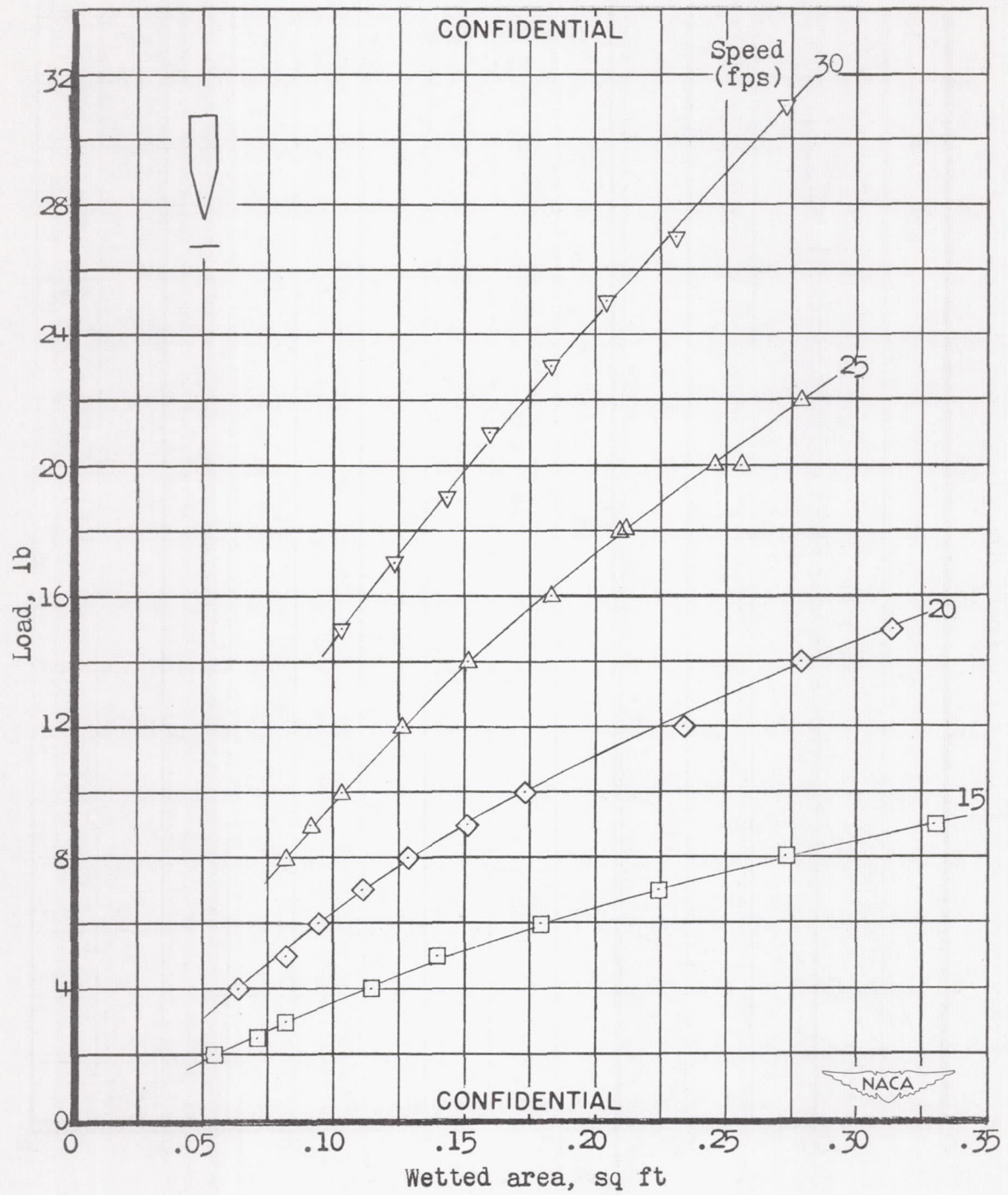
(a) $\tau = 40^\circ$.

Figure 33.- Variation of load with wetted area. Model 250-H.



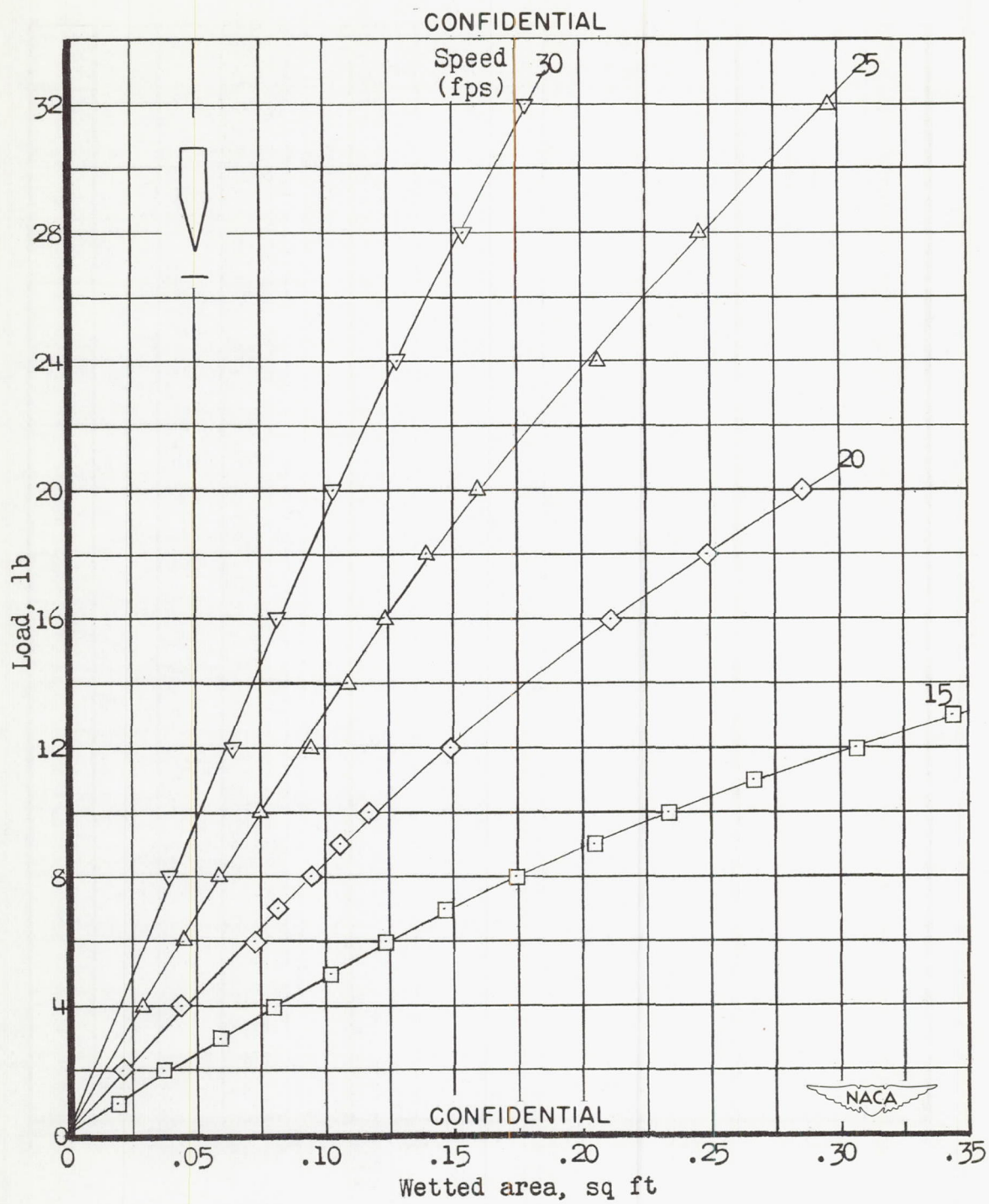
(b) $\tau = 8^\circ$.

Figure 33.- Continued.



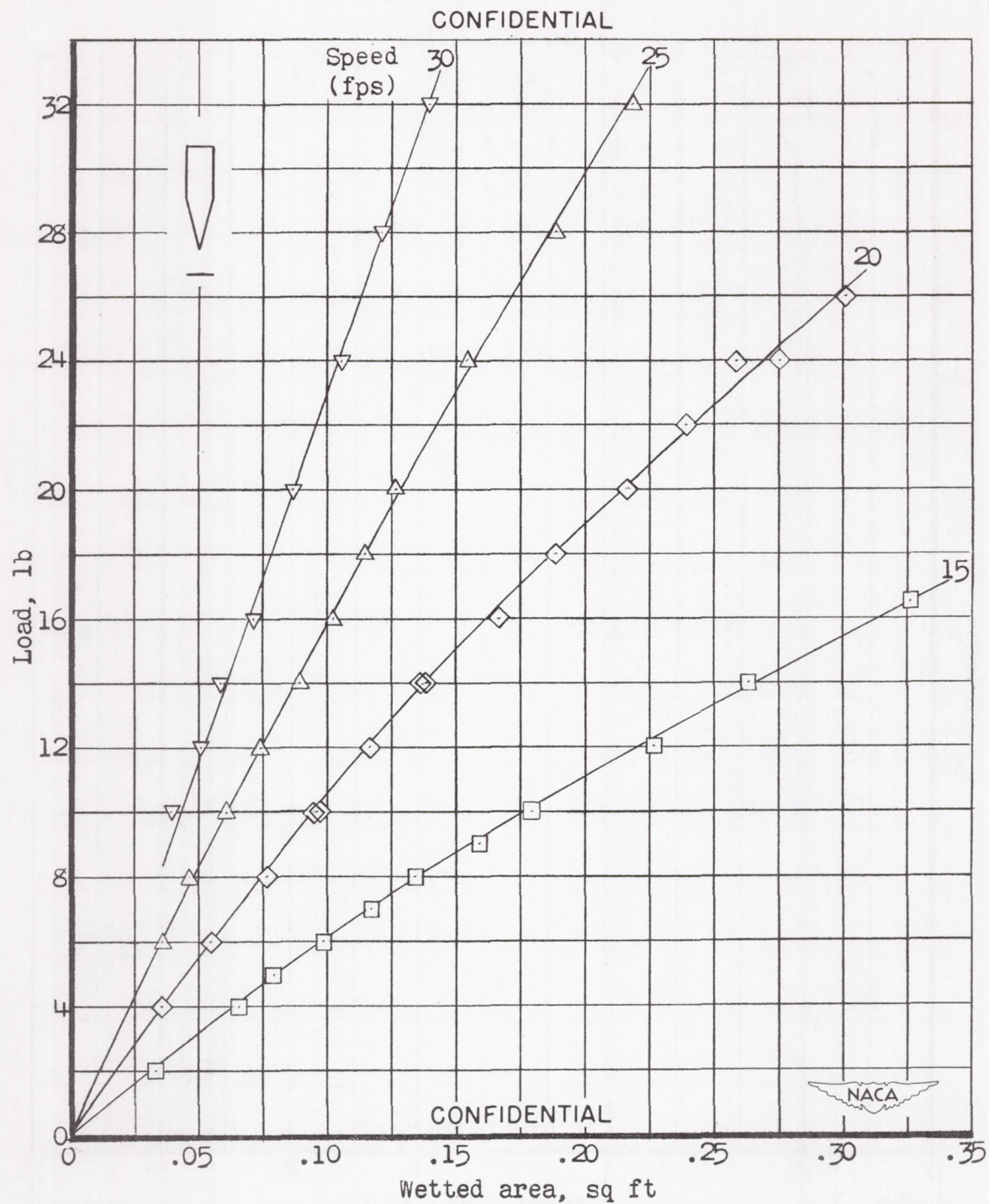
(c) $\tau = 12^\circ$.

Figure 33.- Continued.



(d) $\tau = 16^\circ$.

Figure 33.- Continued.



(e) $\tau = 20^\circ$.

Figure 33.- Concluded.

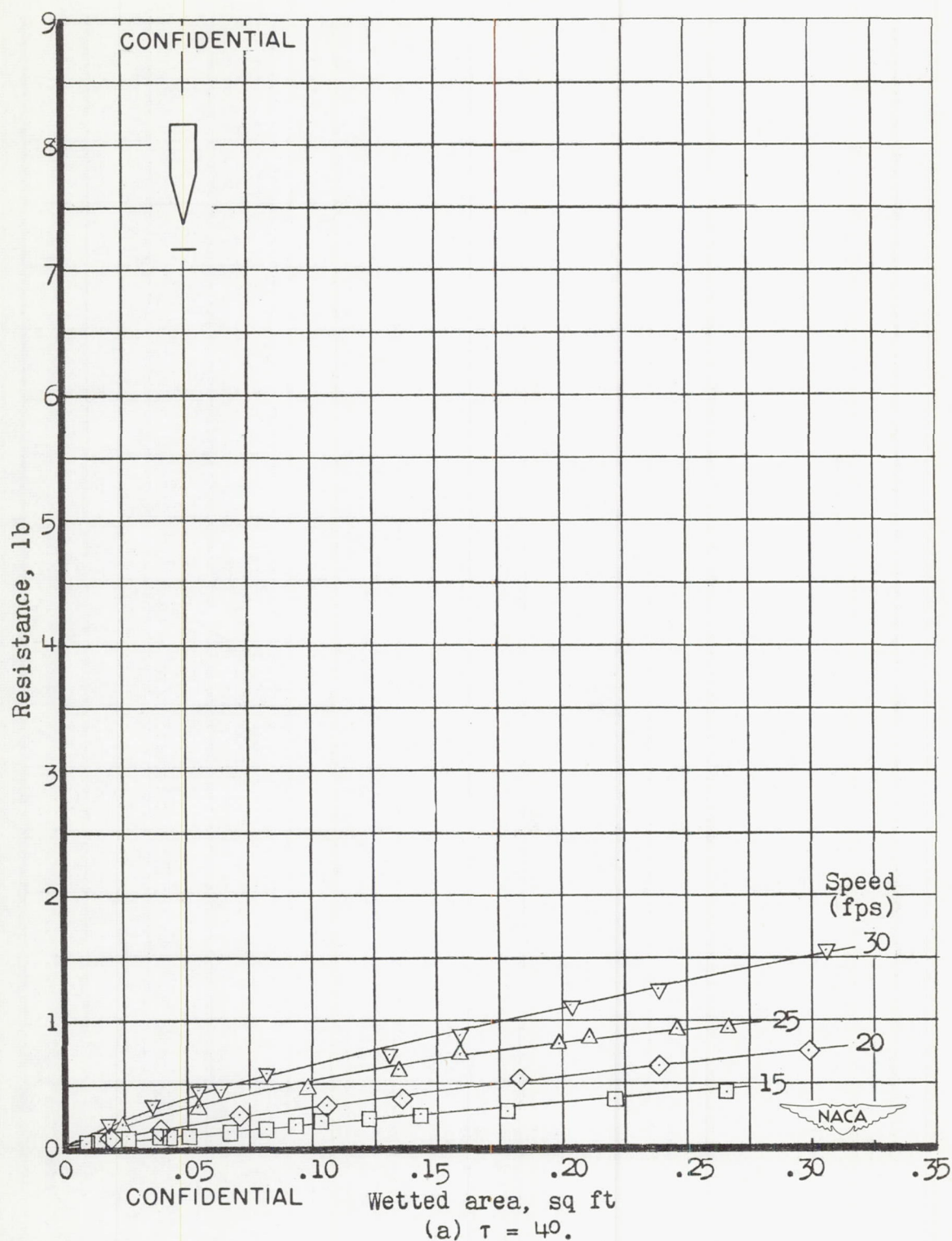
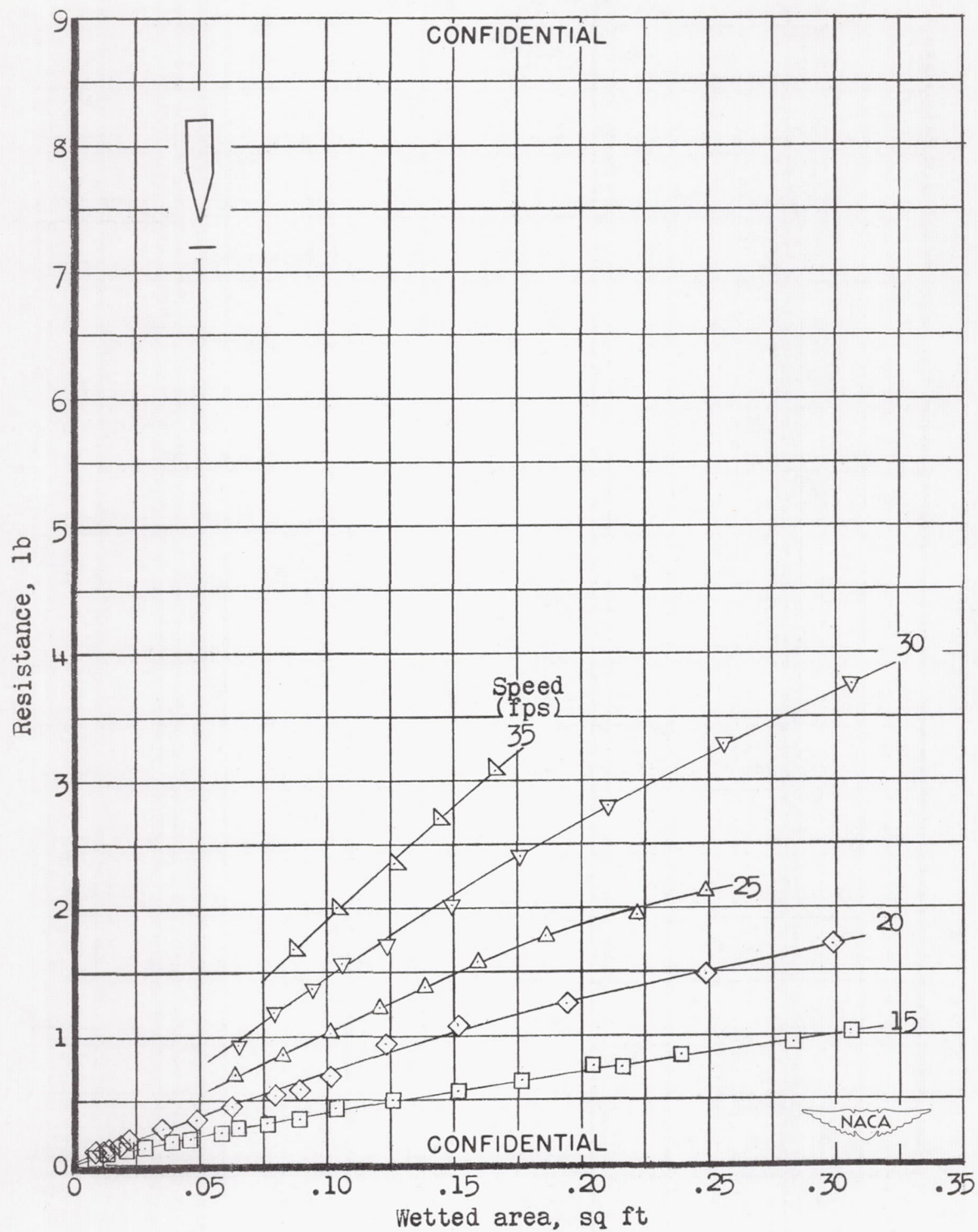
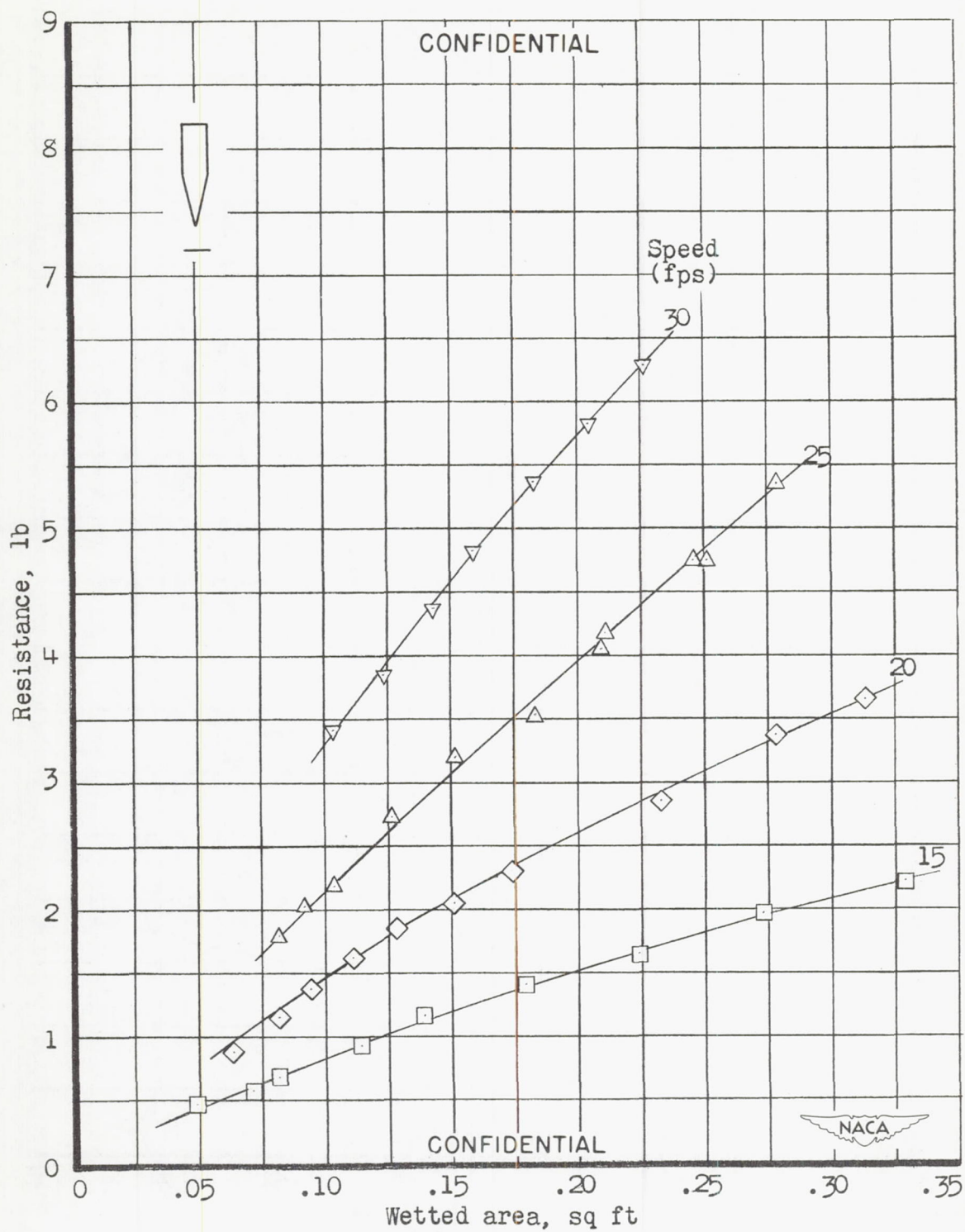


Figure 34.- Variation of resistance with wetted area. Model 250H.



(b) $\tau = 8^\circ$.

Figure 34.- Continued.



(c) $\tau = 12^\circ$.
Figure 34.- Continued.

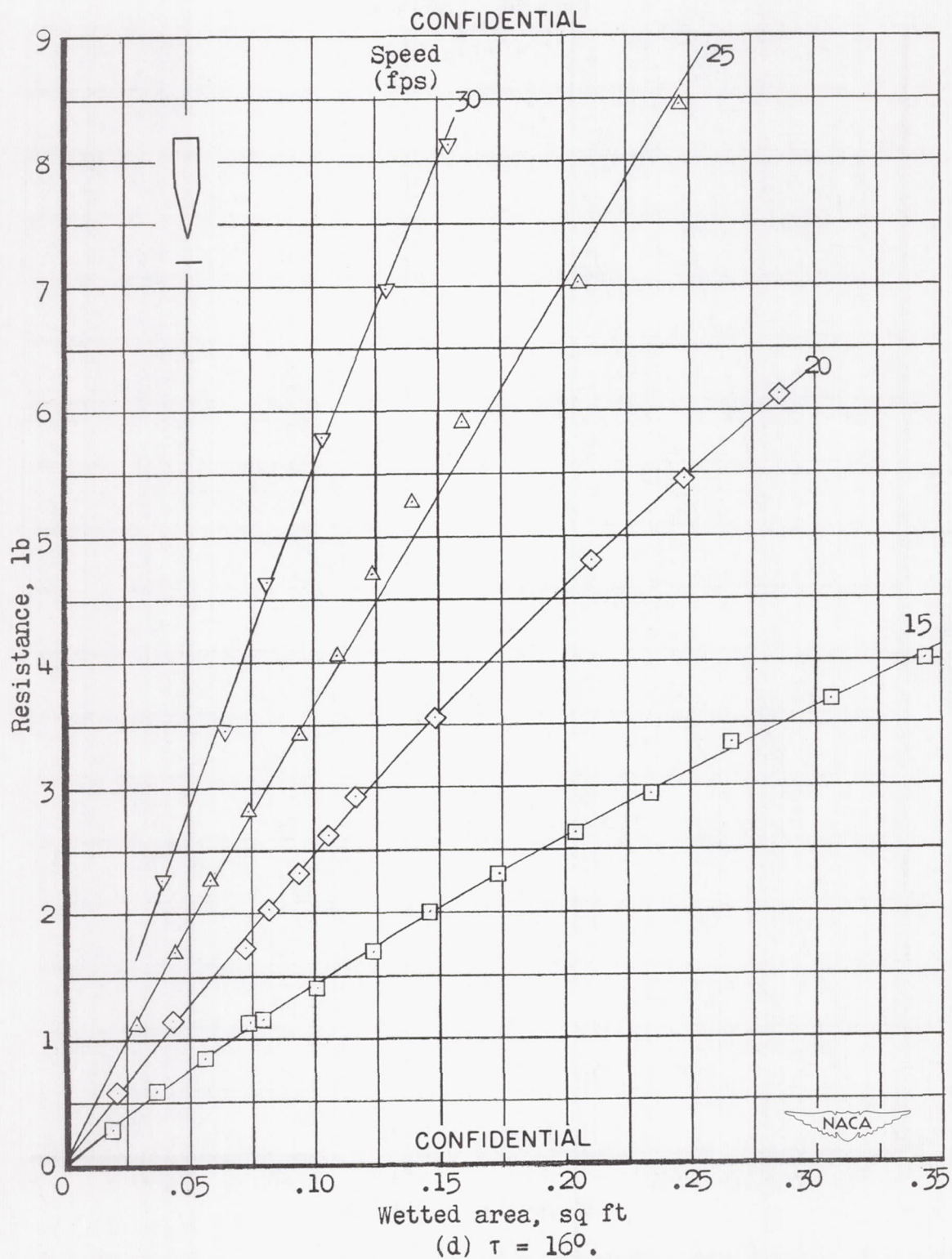


Figure 34.- Continued.

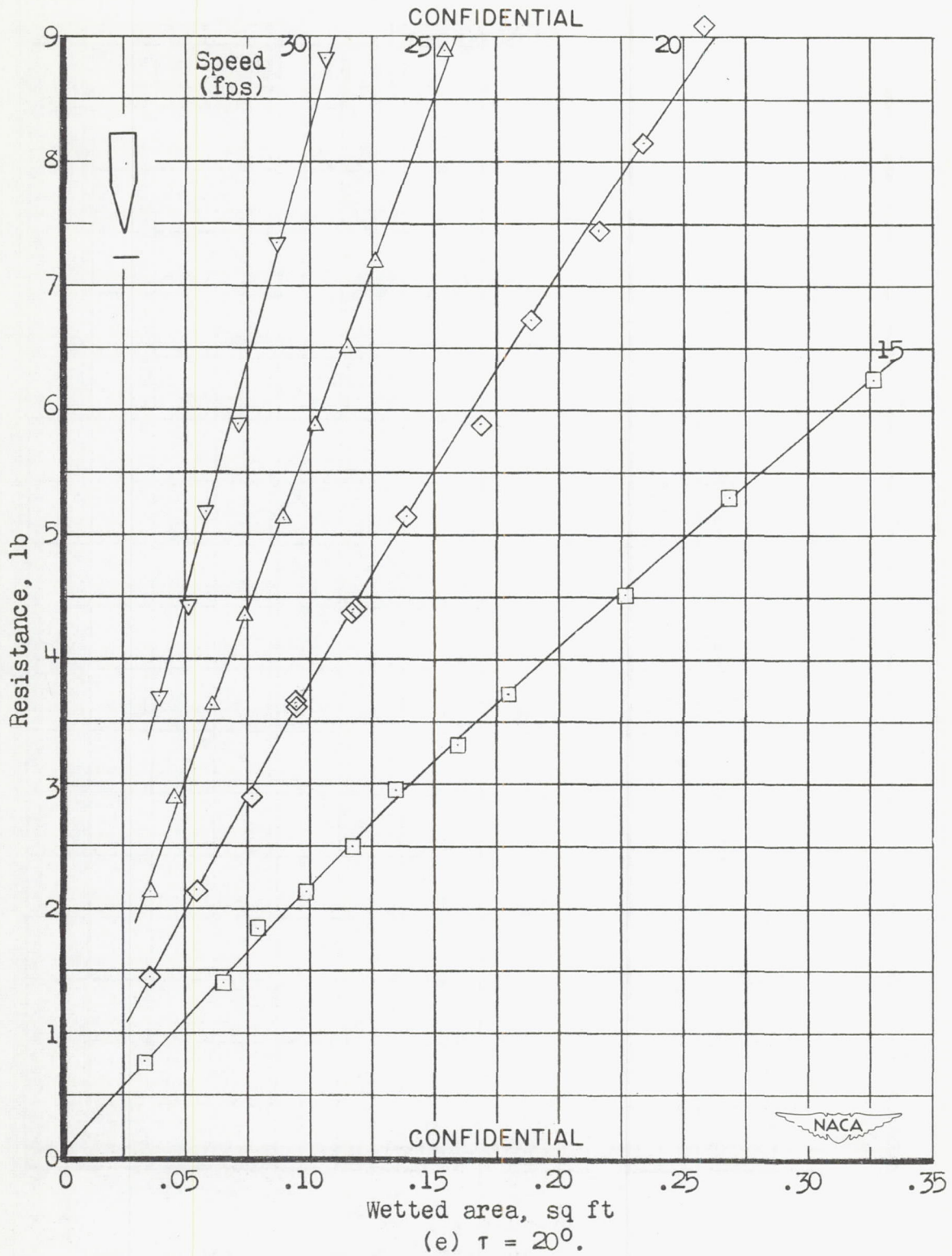


Figure 34.- Concluded.

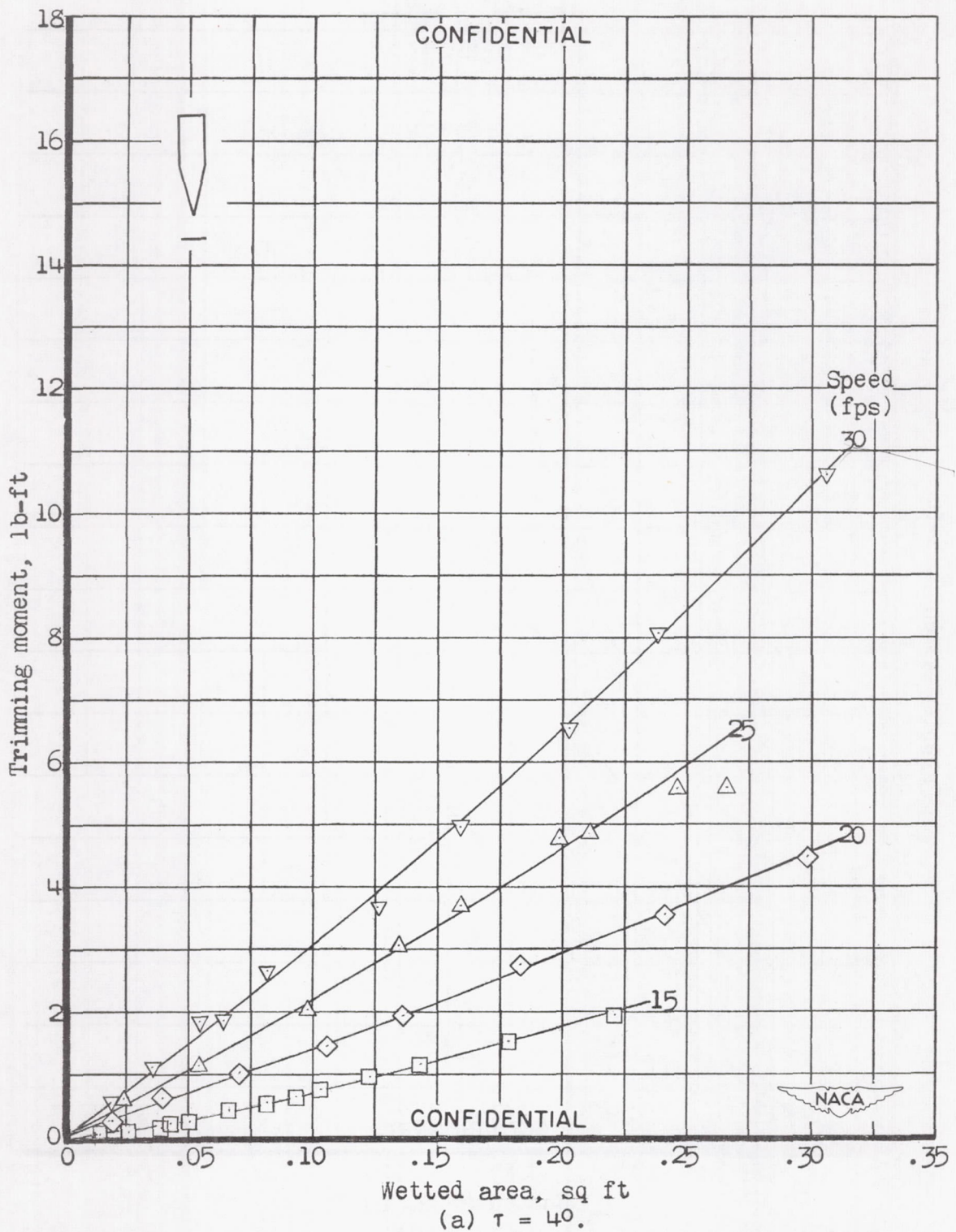


Figure 35.- Variation of moment with wetted area. Model 250H.

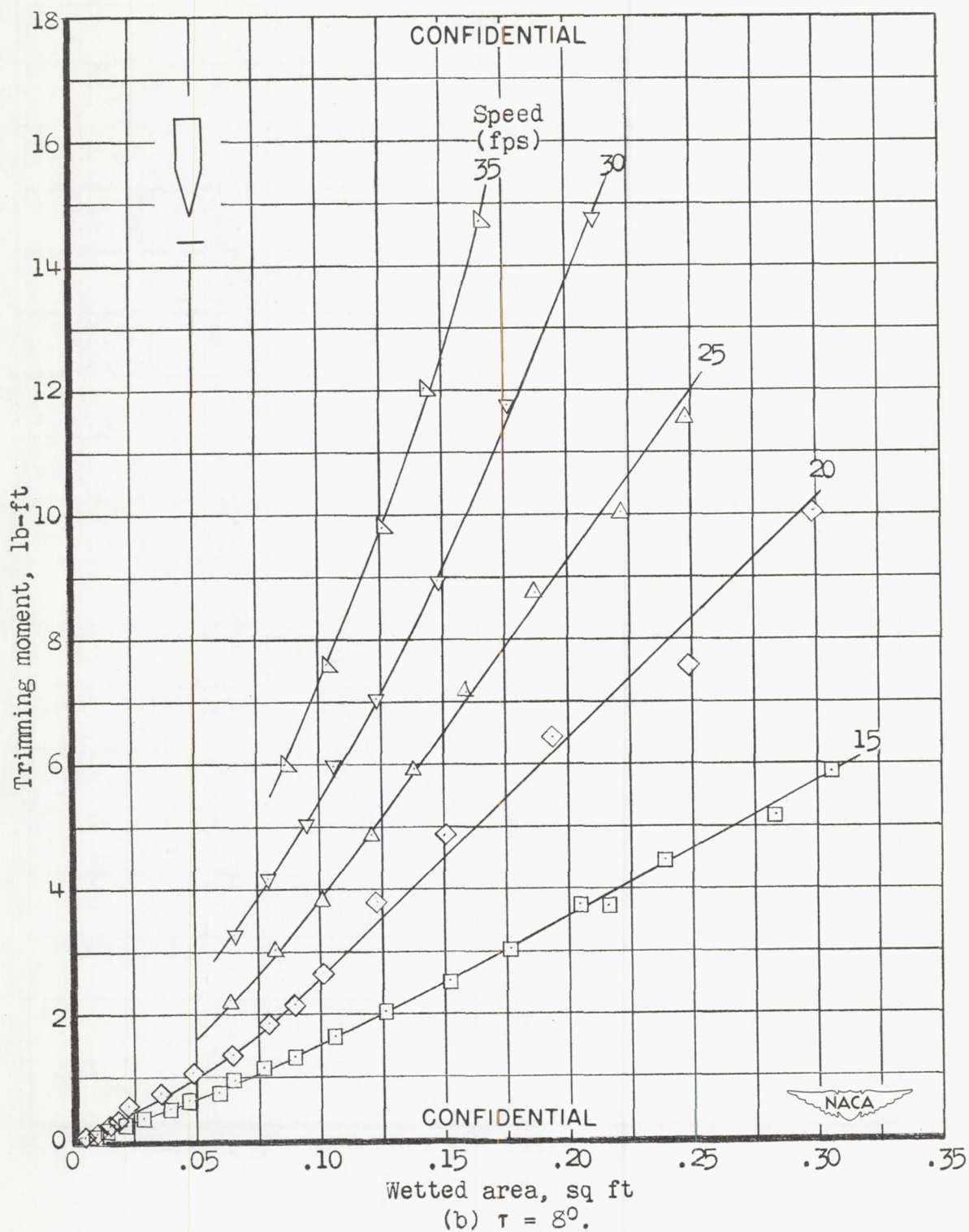


Figure 35.- Continued.

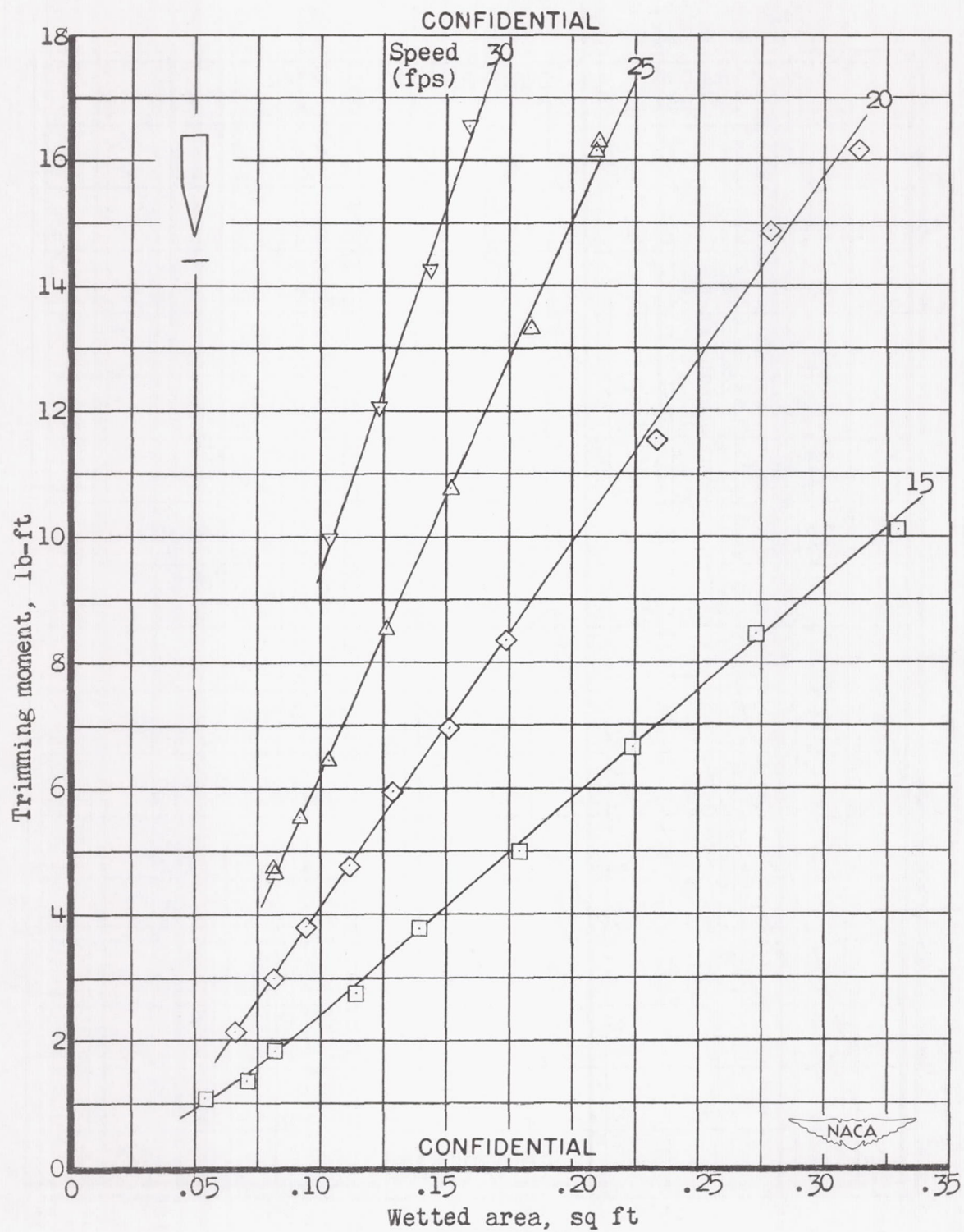


Figure 35.- Continued.

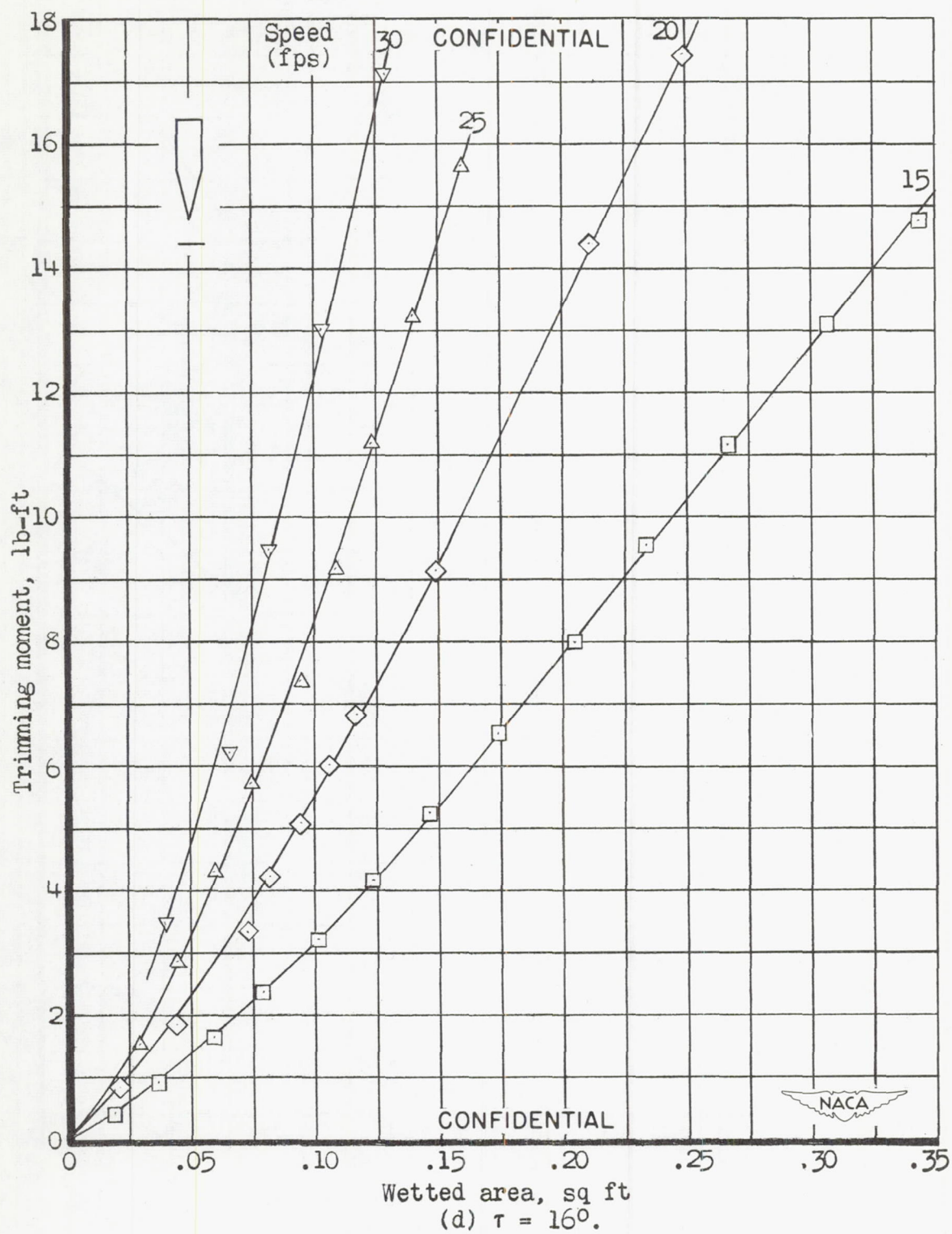
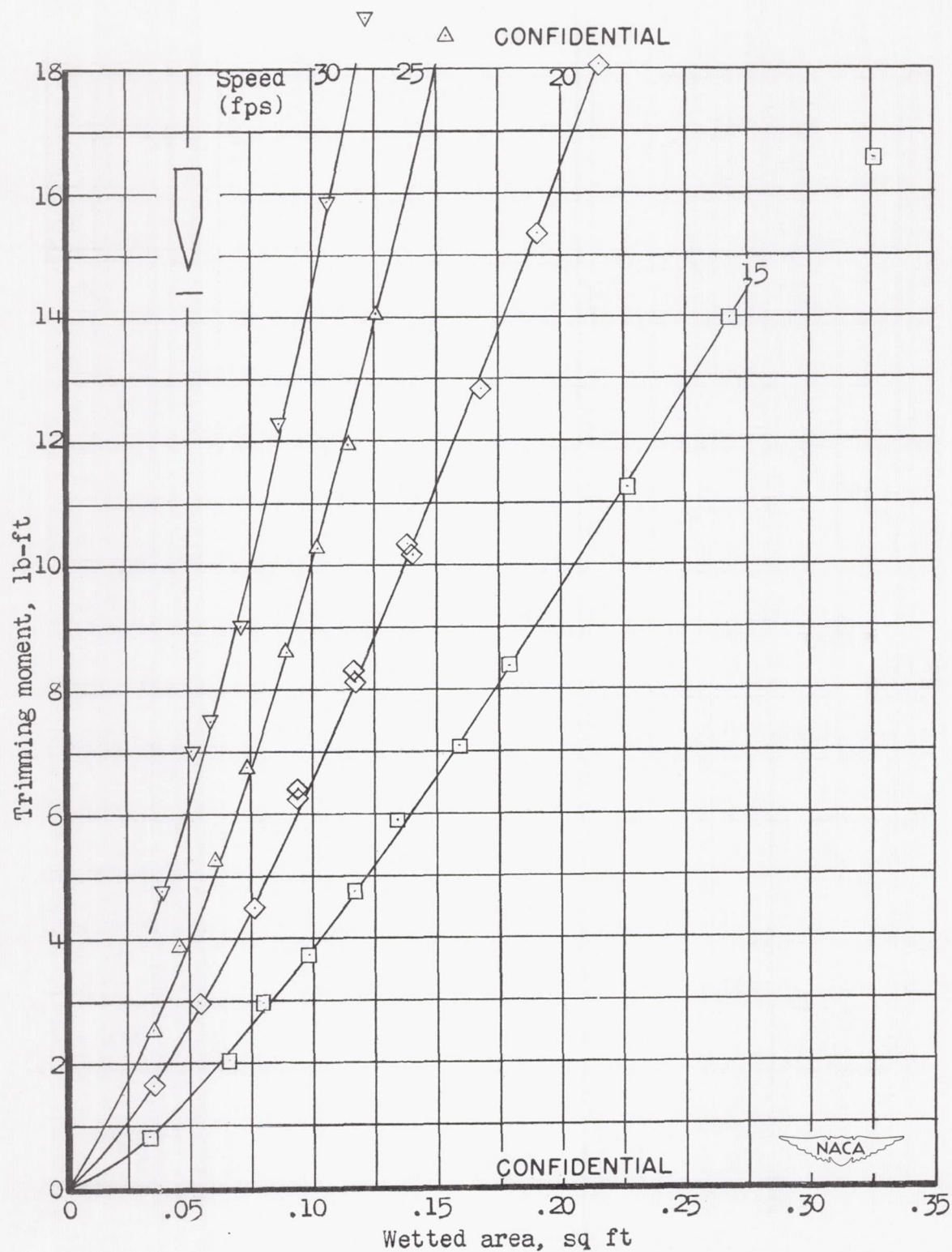
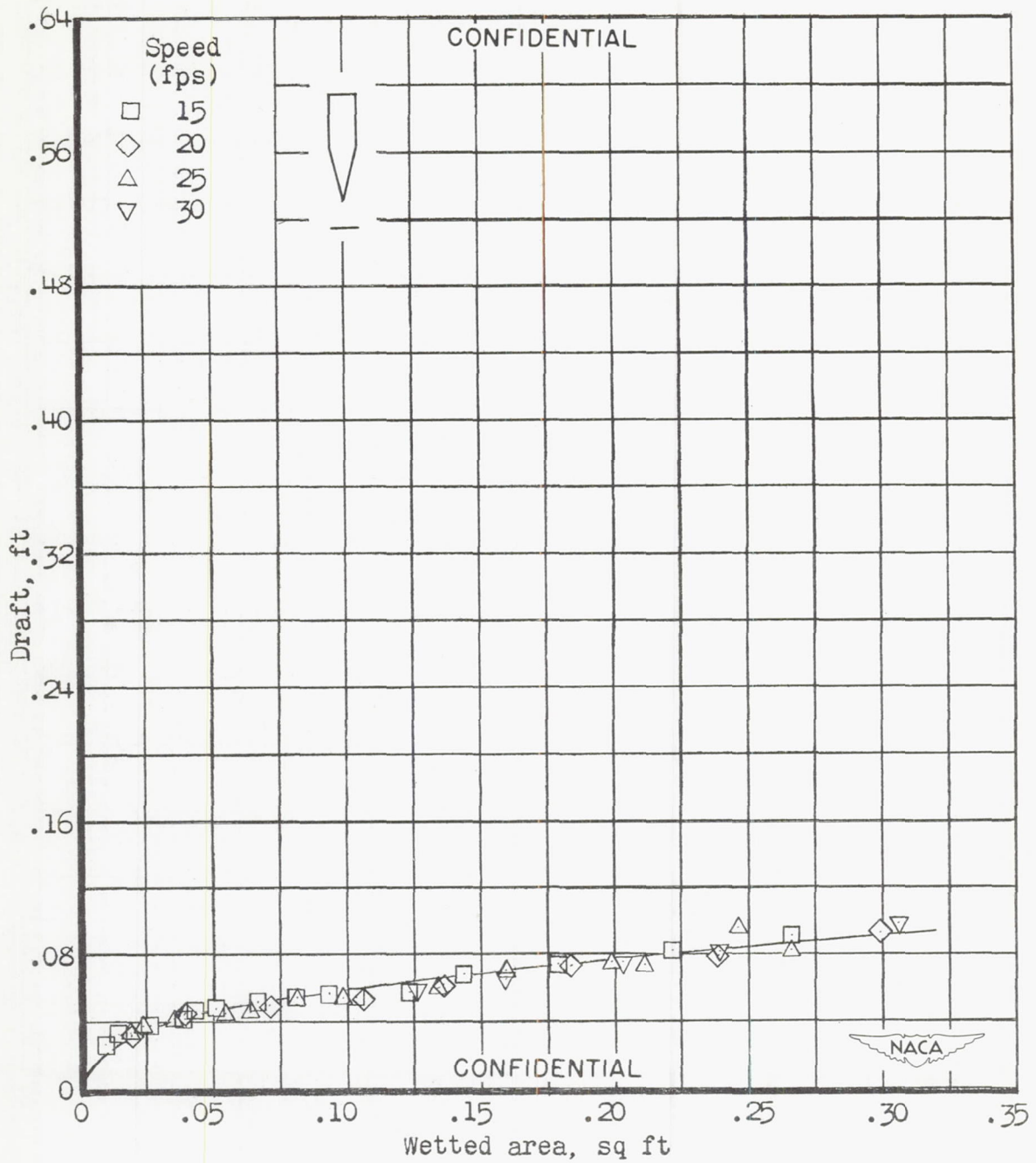


Figure 35.- Continued.

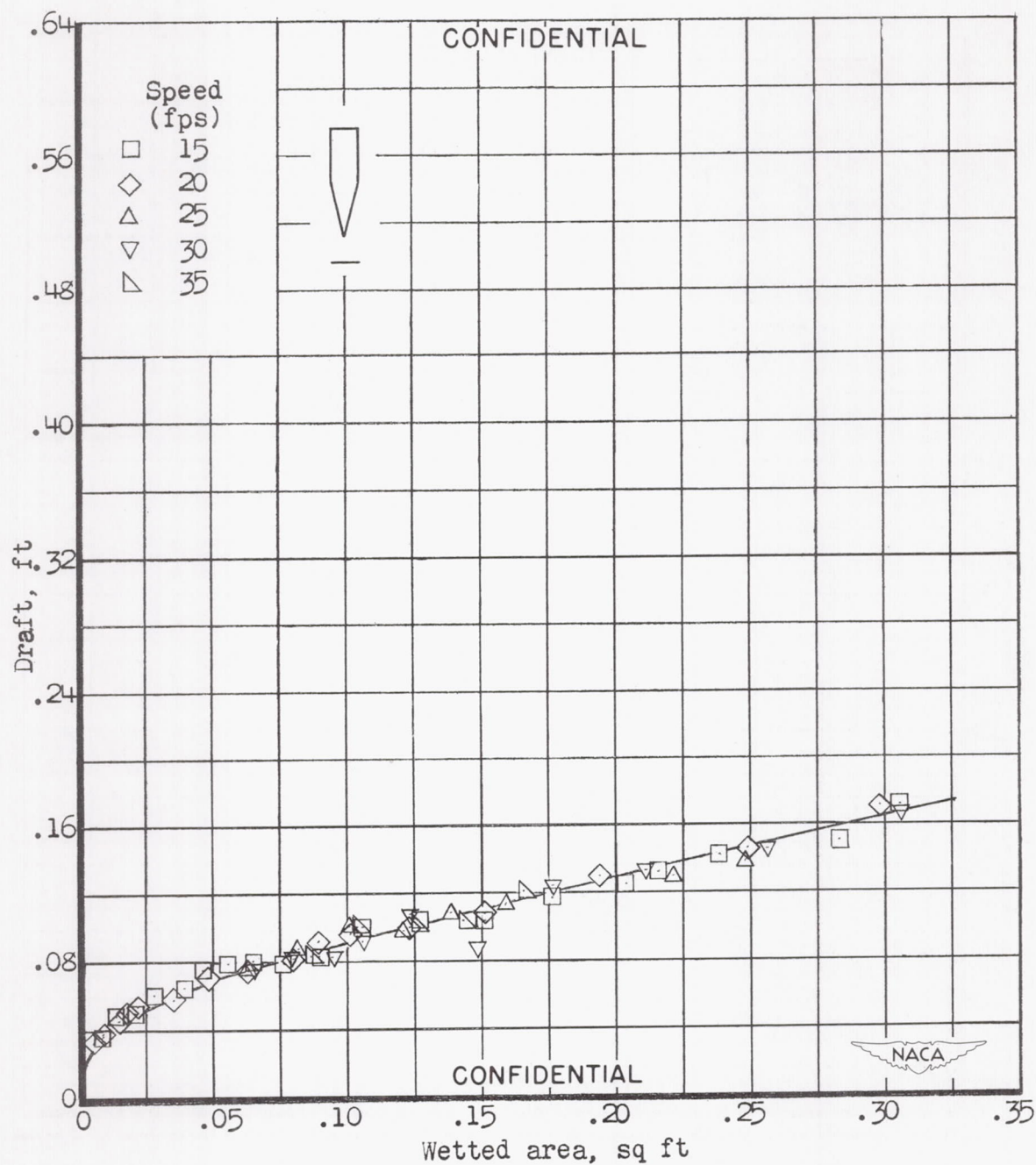


(e) $\tau = 20^\circ$.
Figure 35.- Concluded.



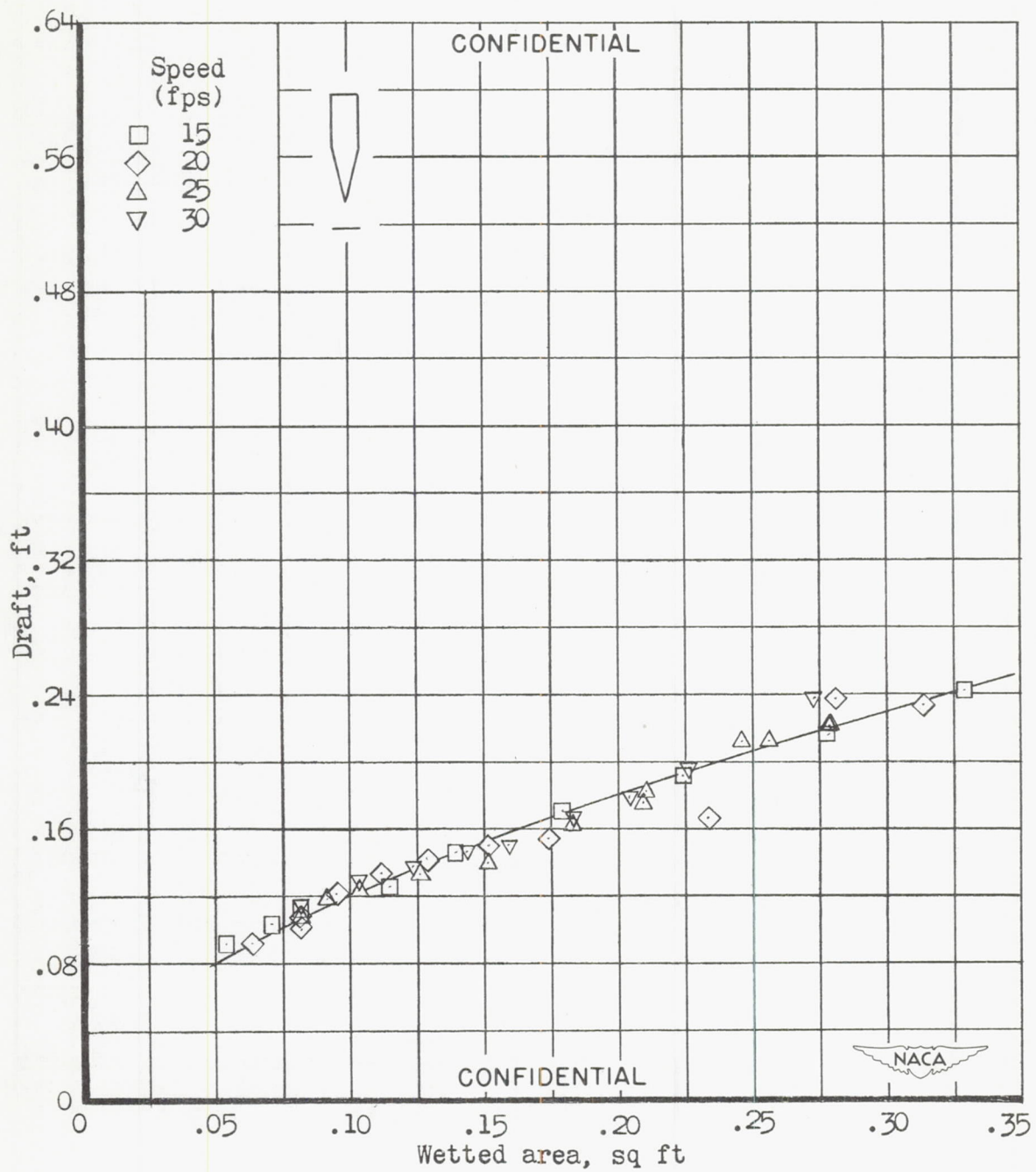
(a) $\tau = 4^\circ$.

Figure 36.- Variation of draft with wetted area. Model 250H.



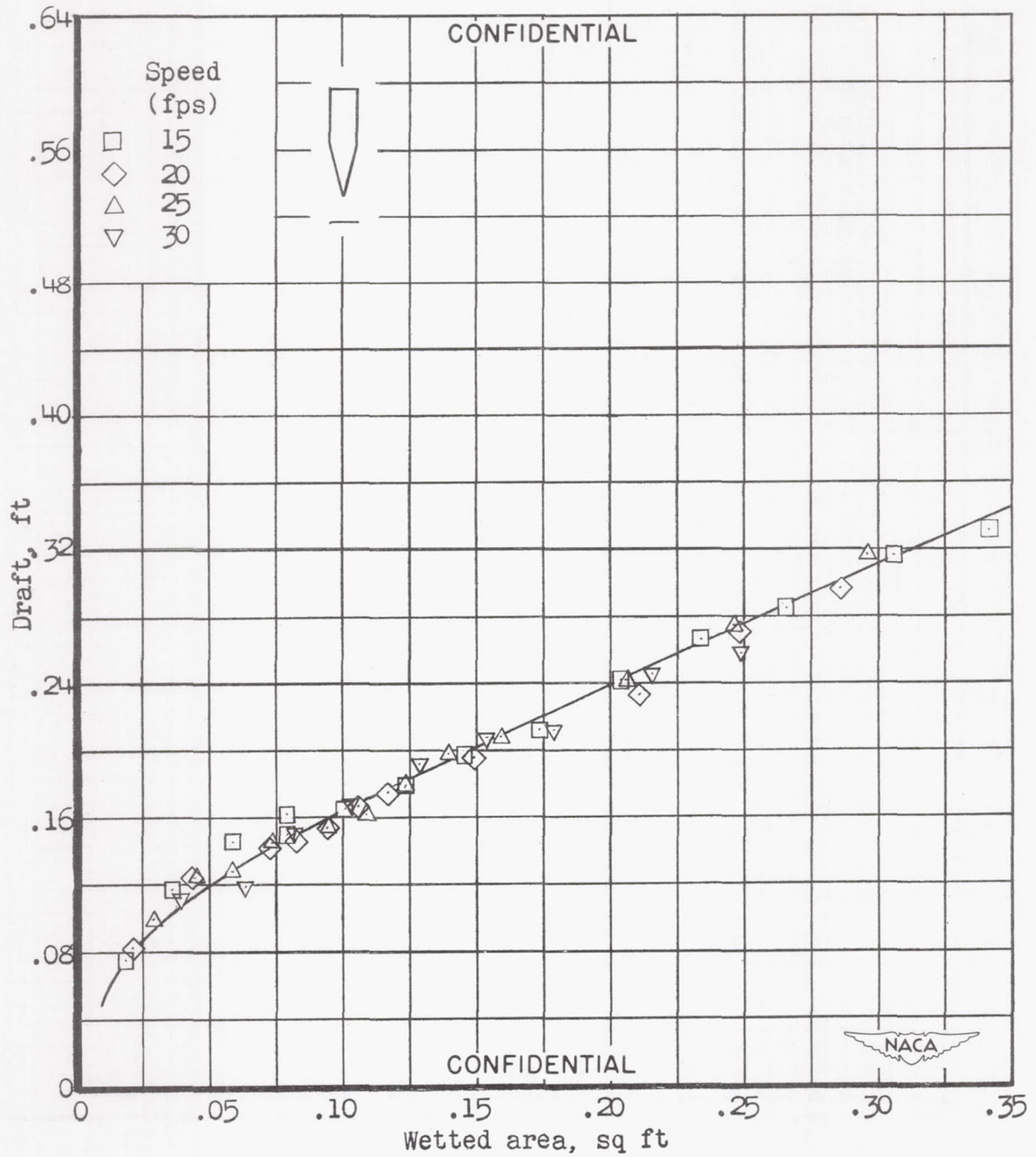
(b) $\tau = 8^\circ$.

Figure 36.- Continued.



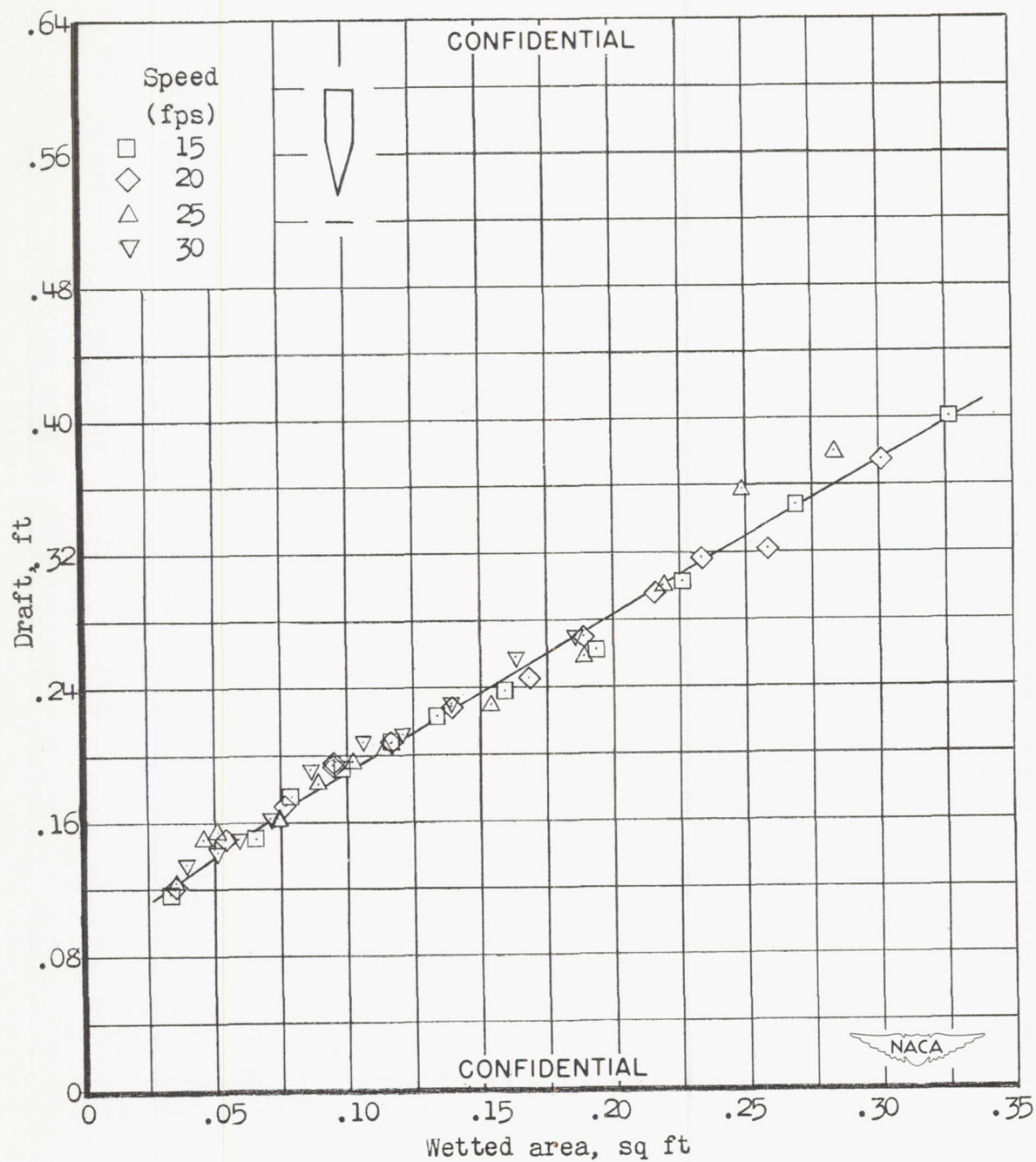
(c) $\tau = 12^\circ$.

Figure 36.- Continued.



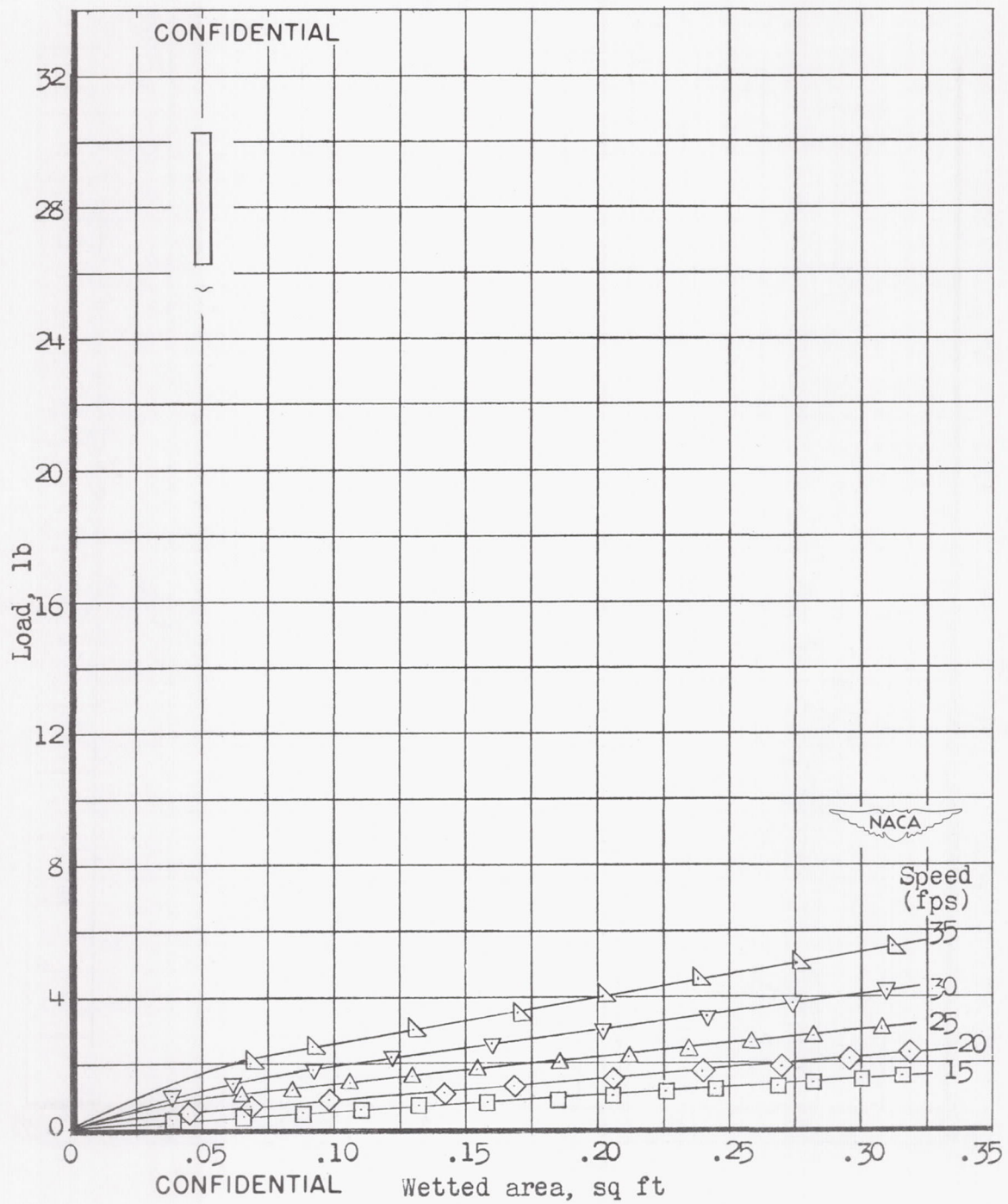
(d) $\tau = 16^\circ$.

Figure 36.- Continued.



(e) $\tau = 20^\circ$.

Figure 36.- Concluded.



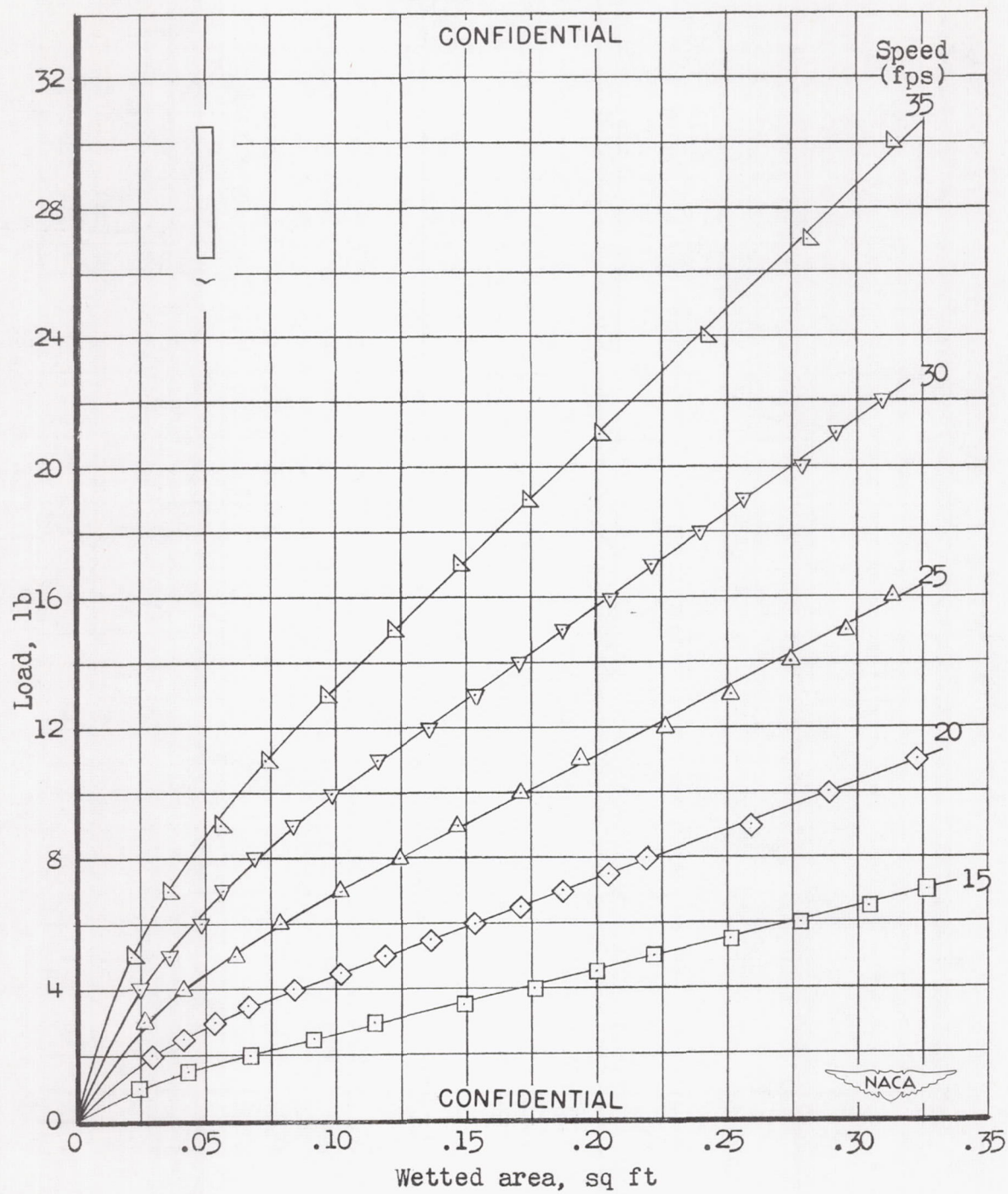
(a) $\tau = 4^\circ$.

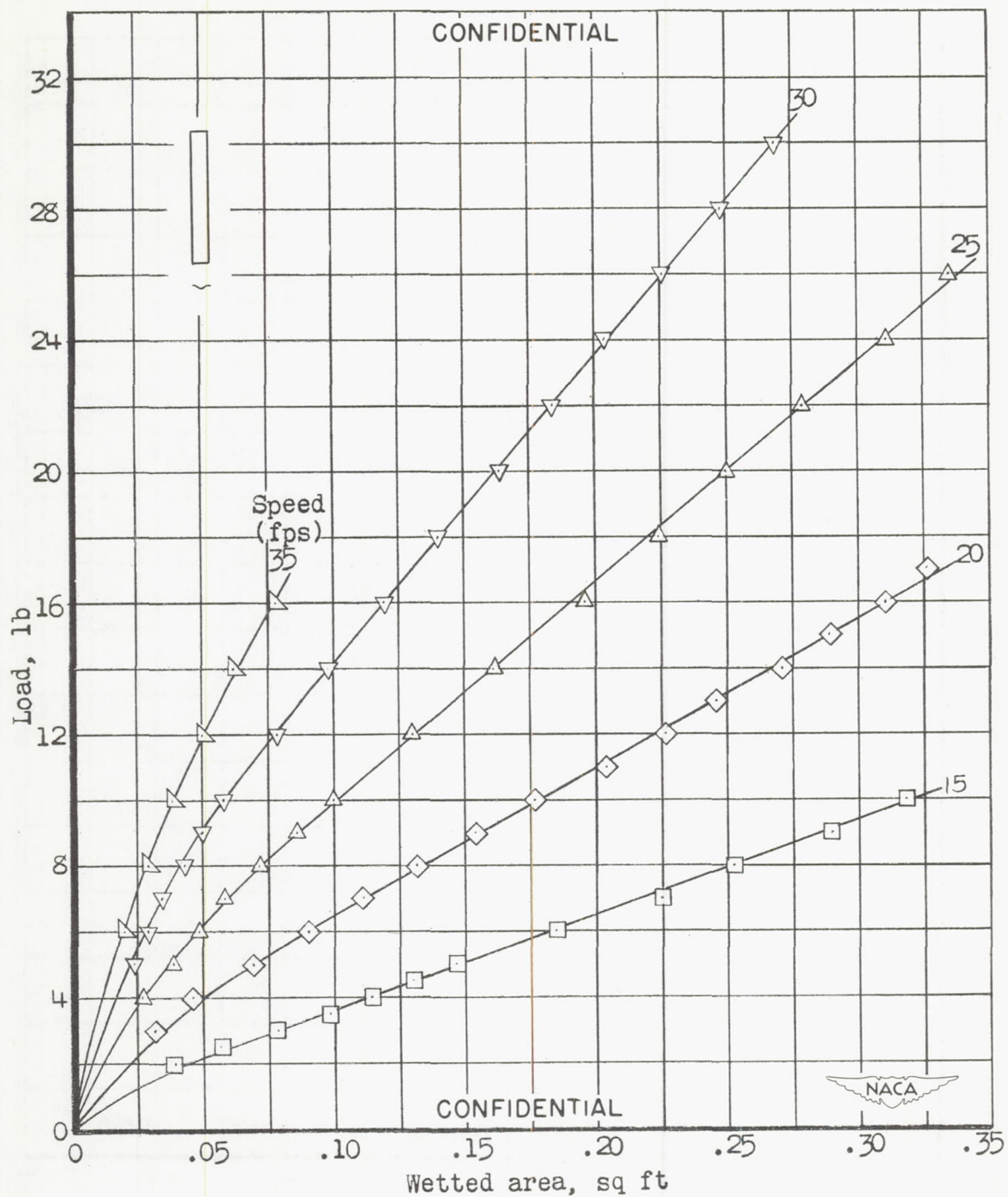
Figure 37.- Variation of load with wetted area. Model 250J.



(b) $\tau = 8^\circ$.

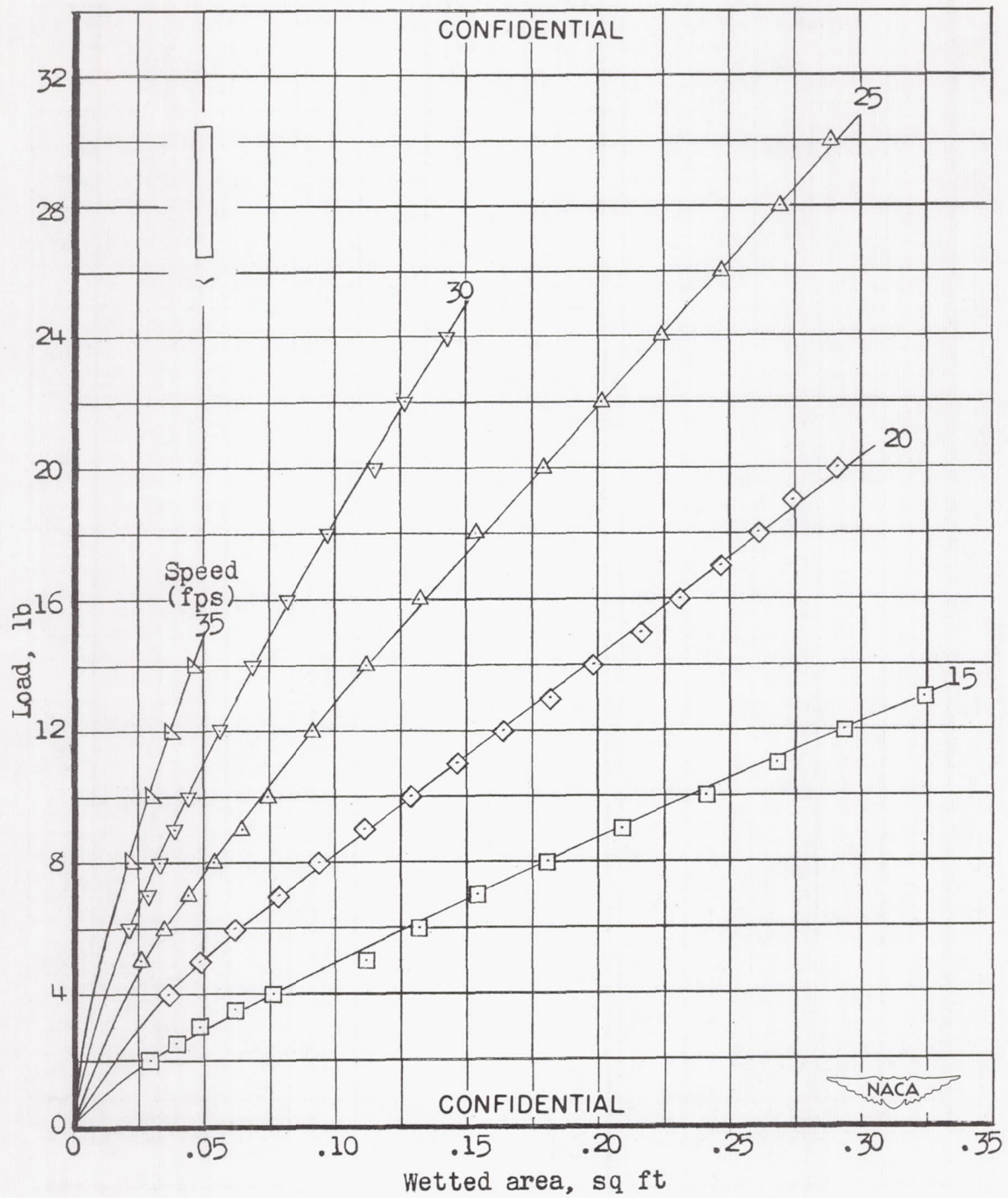
Figure 37.- Continued.





(d) $\tau = 16^\circ$.

Figure 37.- Continued.



(e) $\tau = 20^\circ$.

Figure 37.- Concluded.

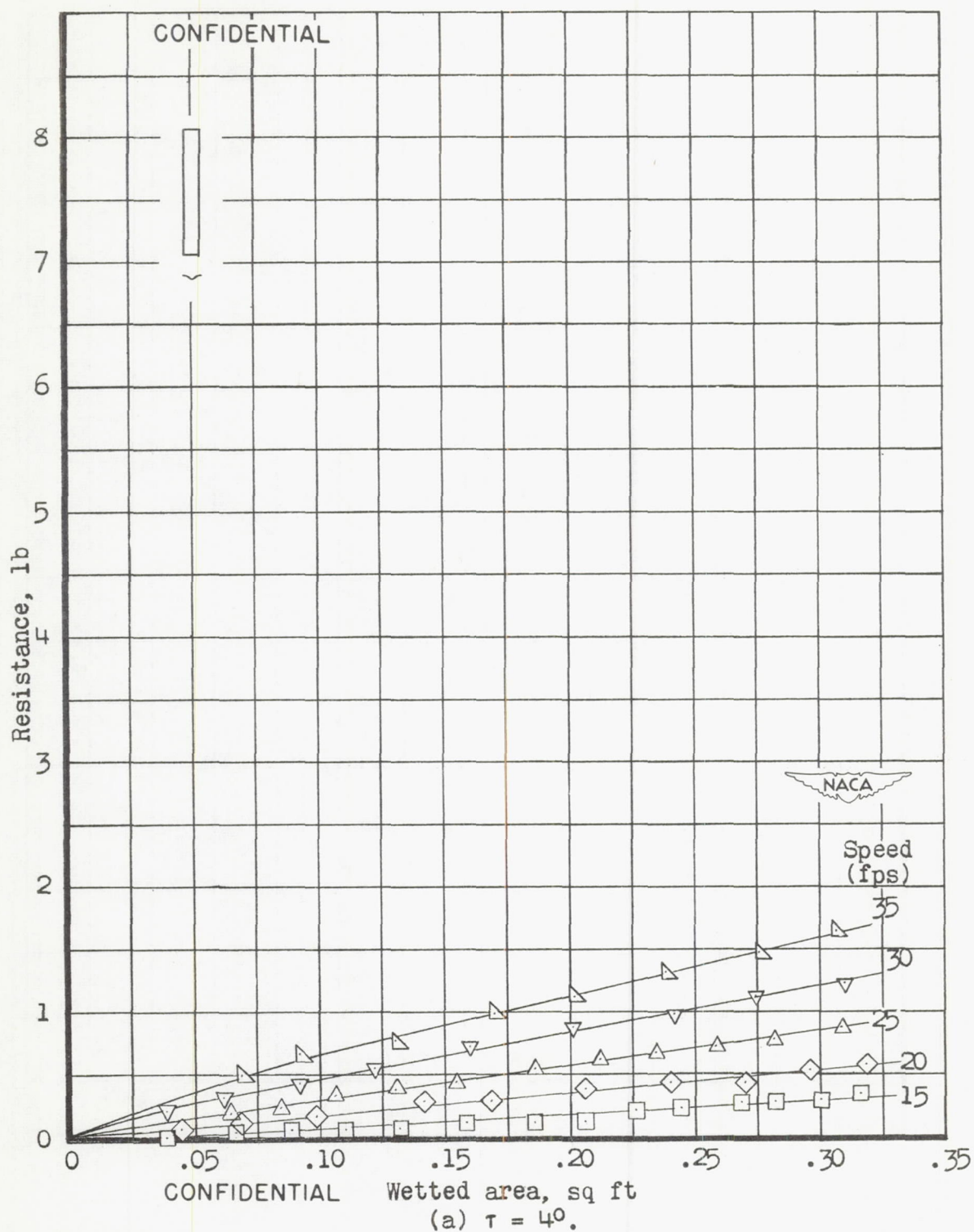


Figure 38.- Variation of resistance with wetted area. Model 250J.

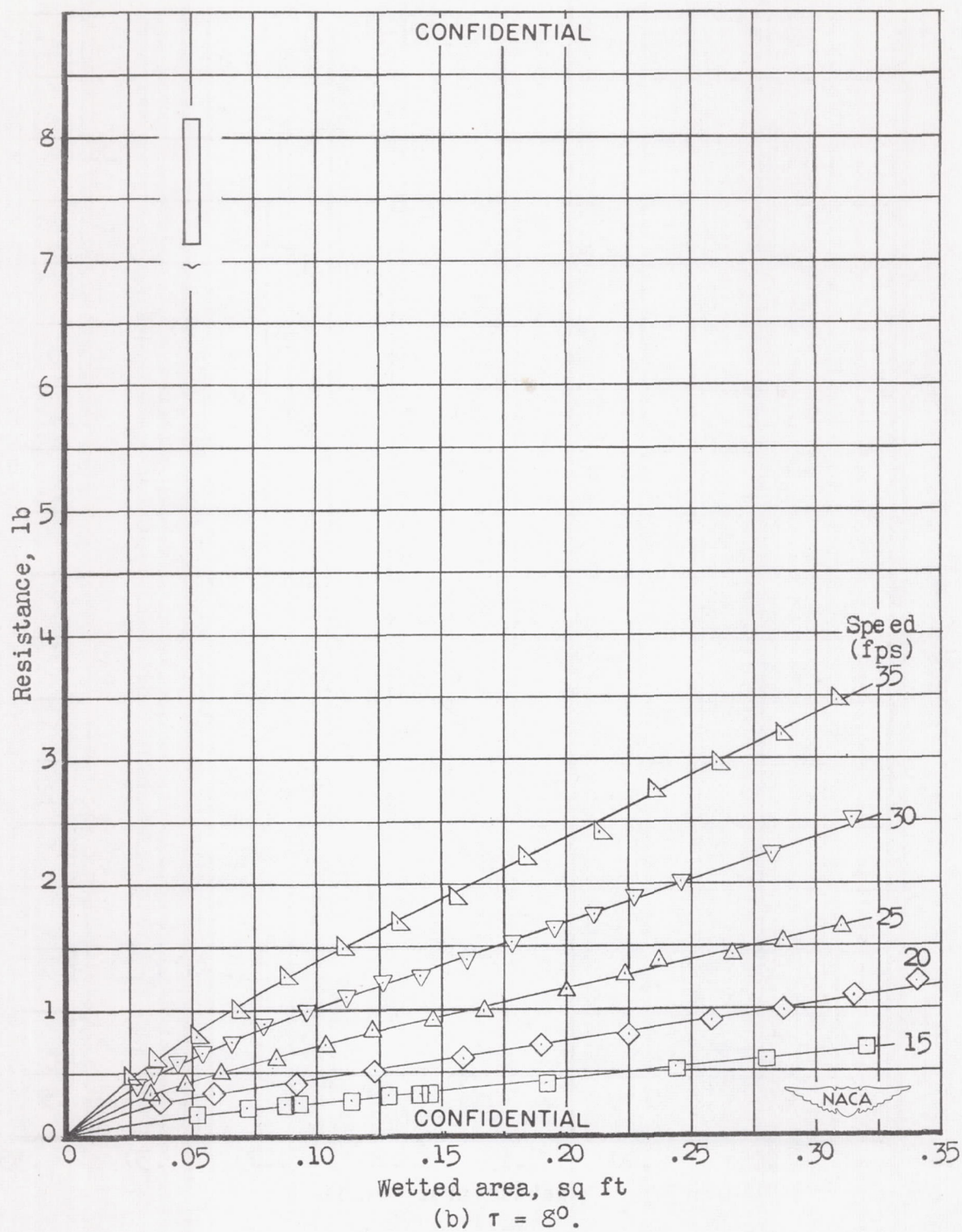
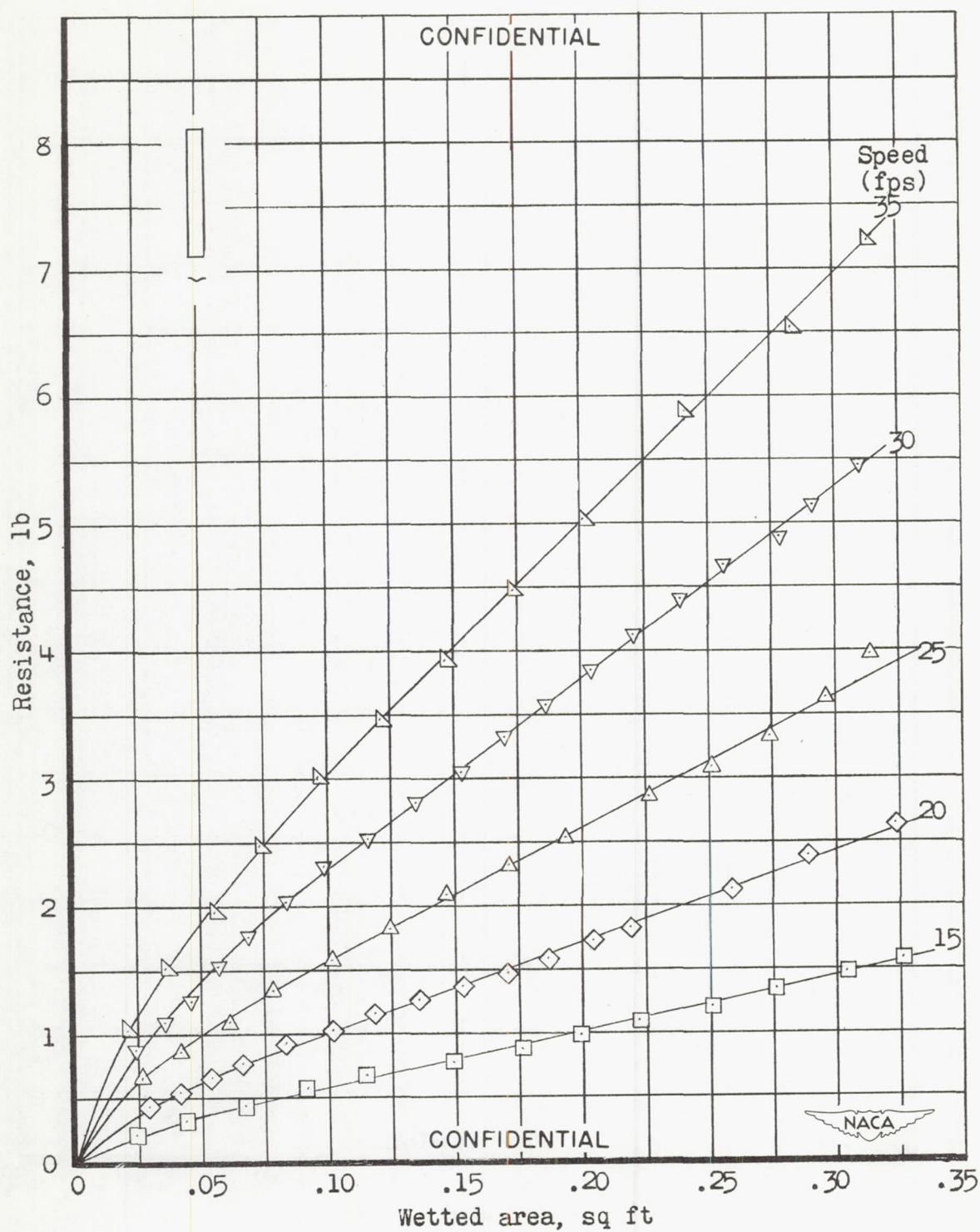


Figure 38.- Continued.



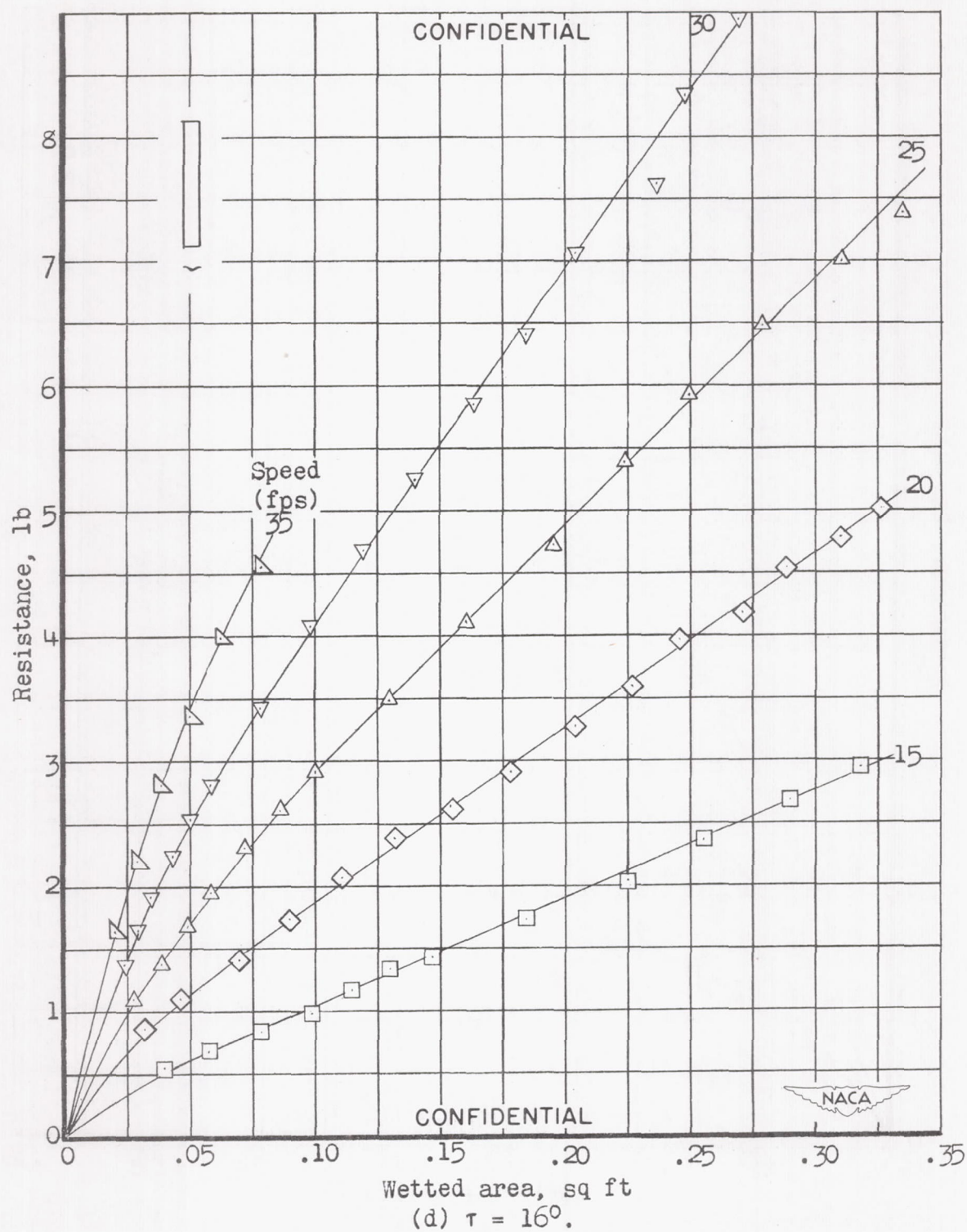
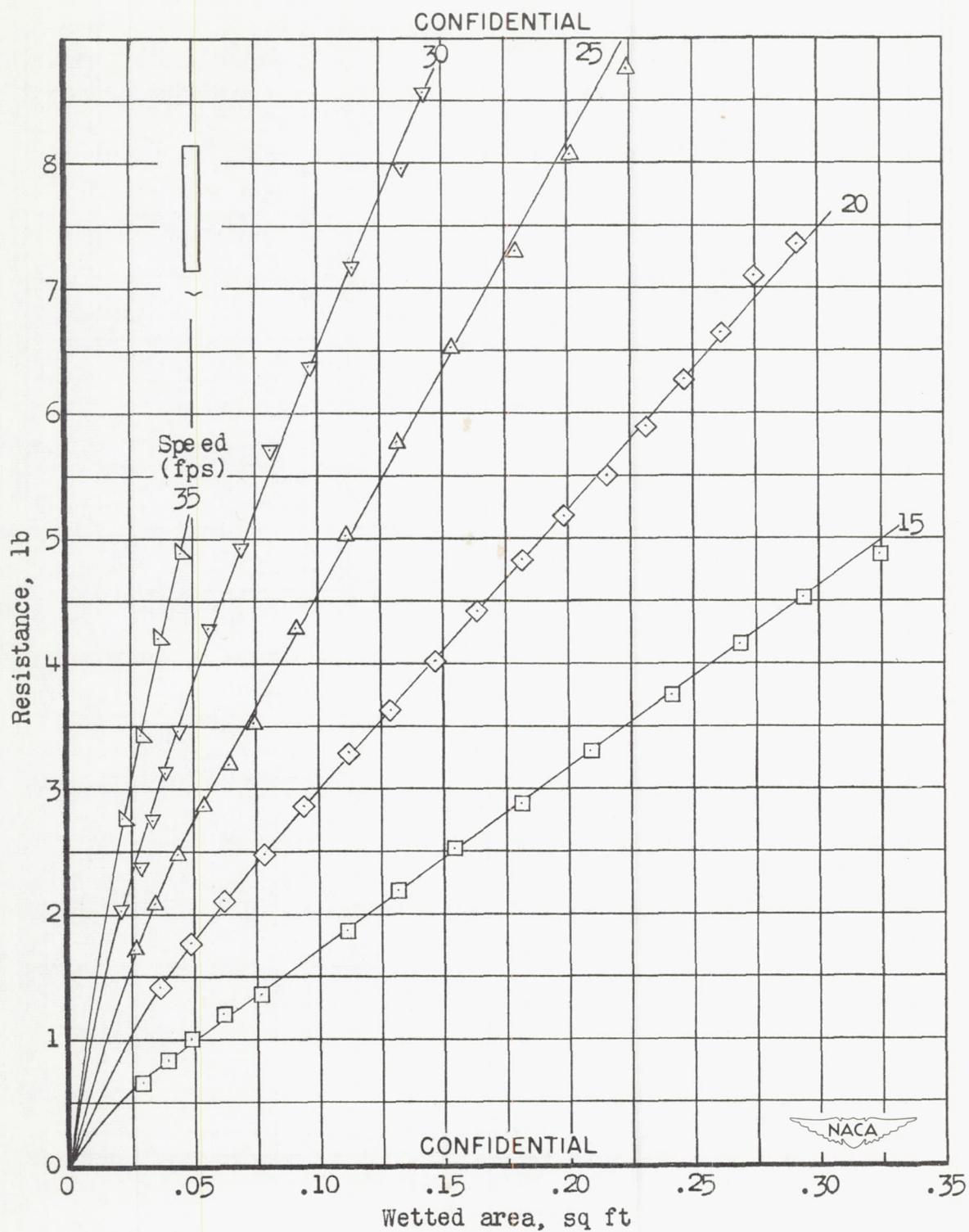
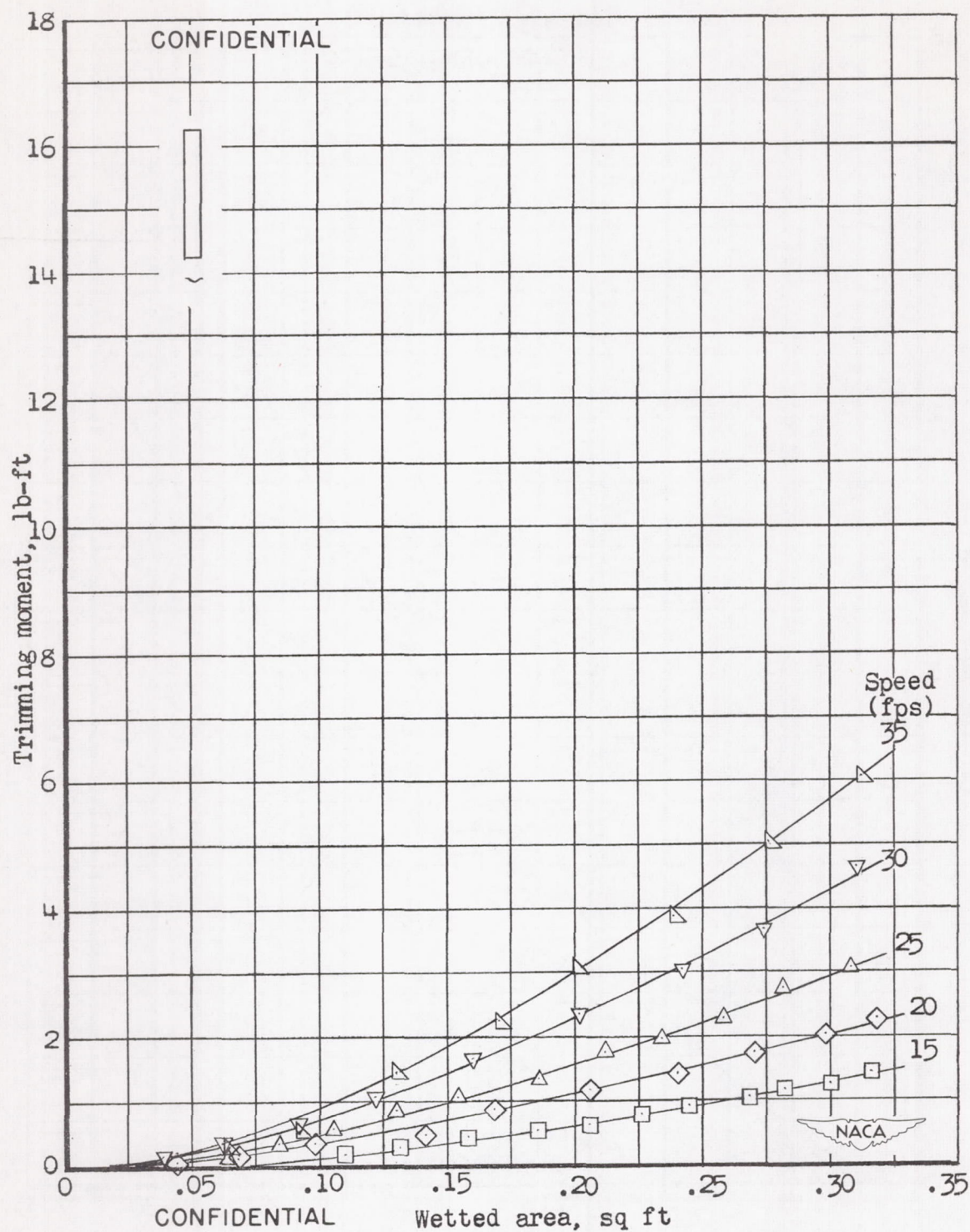


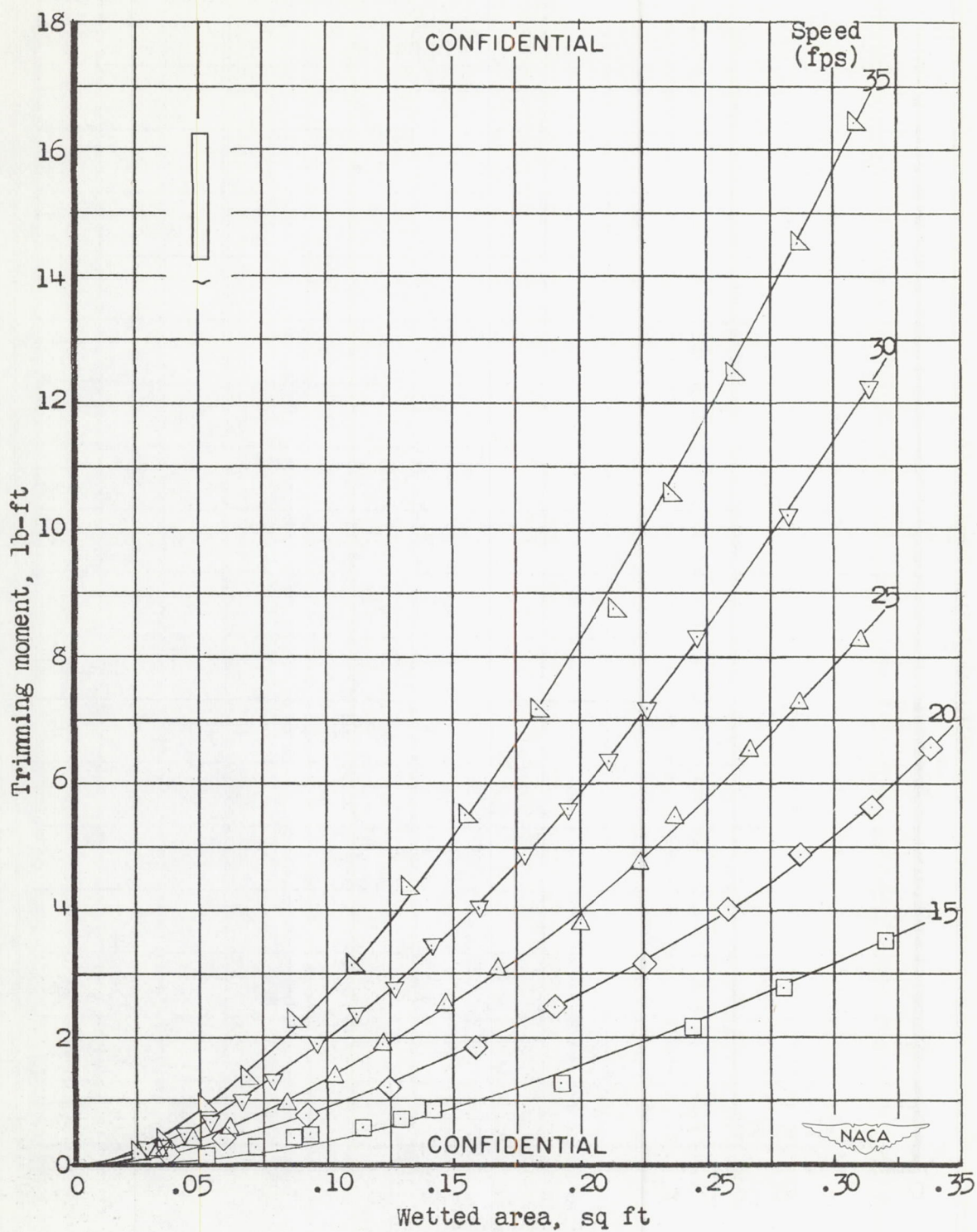
Figure 38.- Continued.



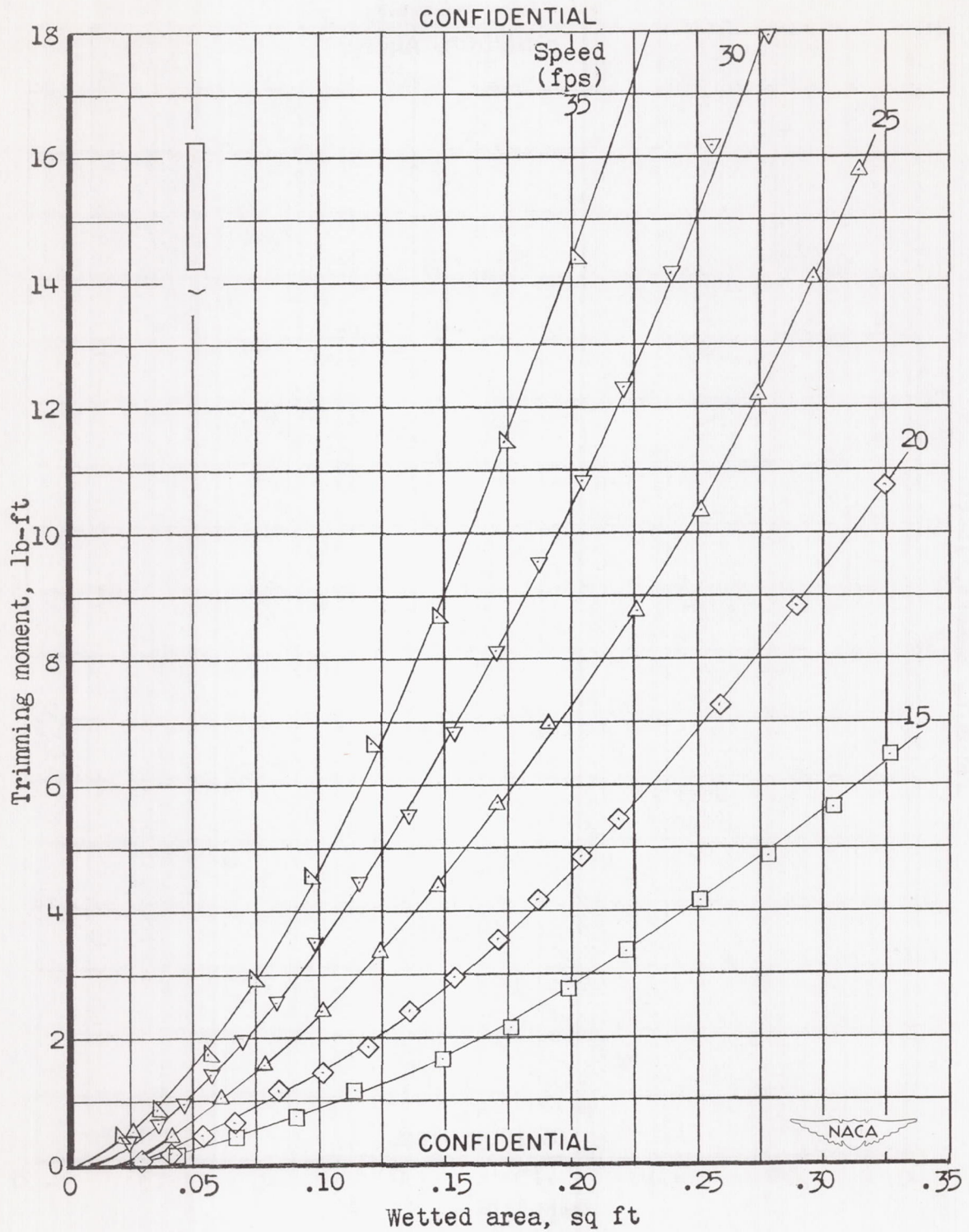
(e) $\tau = 20^\circ$.
Figure 38.- Concluded.



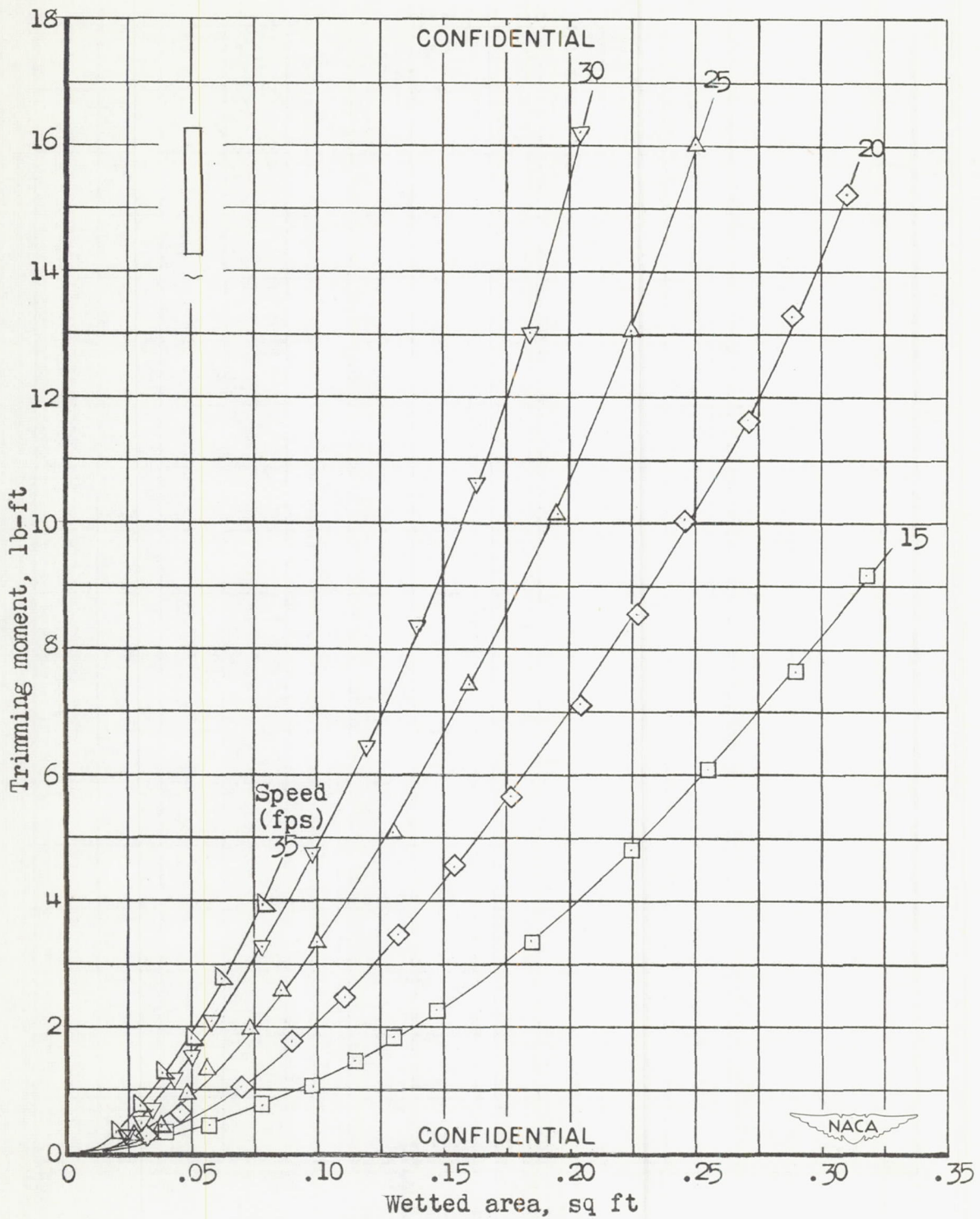
(a) $\tau = 4^\circ$.
Figure 39.- Variation of moment with wetted area. Model 250J.



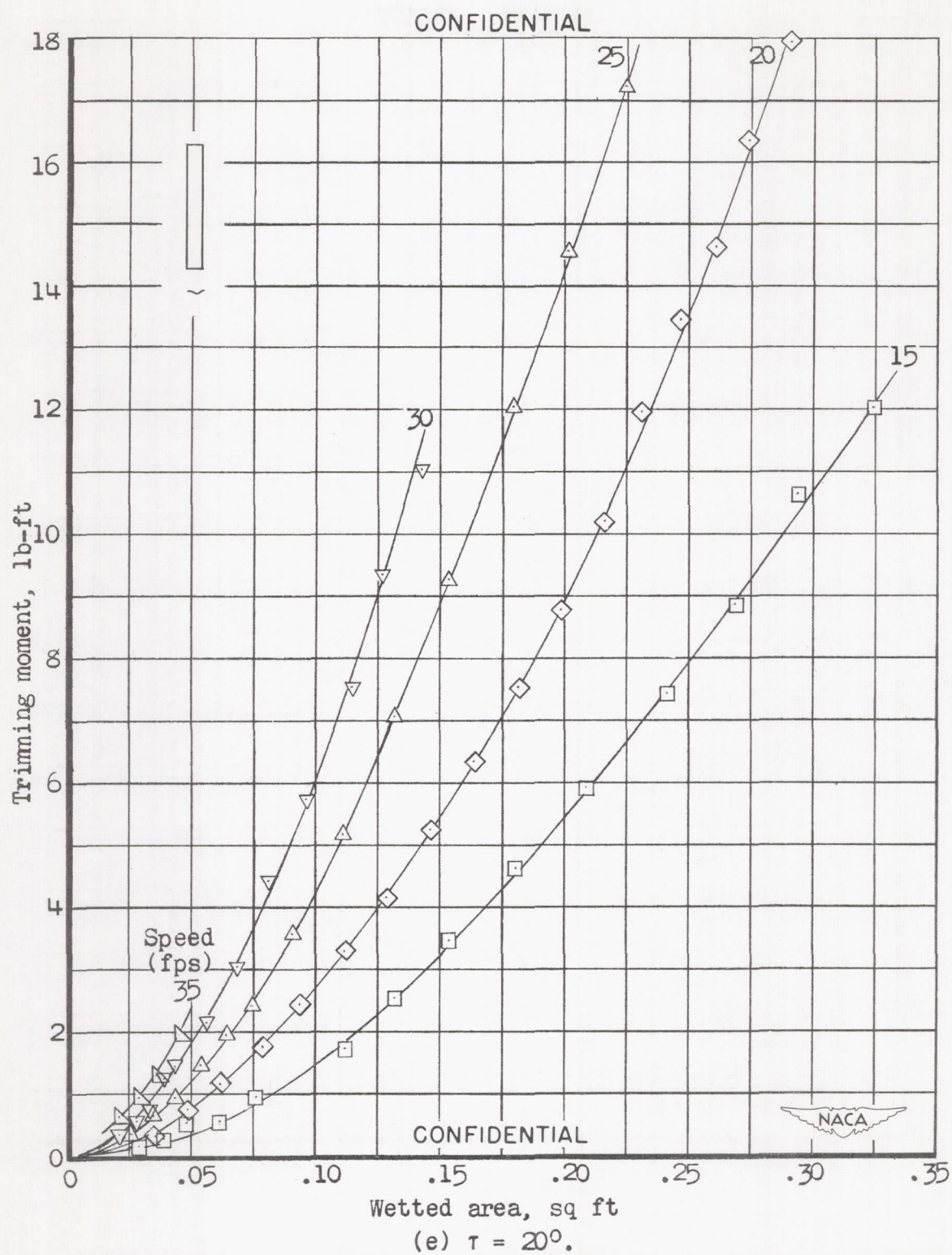
(b) $\tau = 8^\circ$.
Figure 39.- Continued.



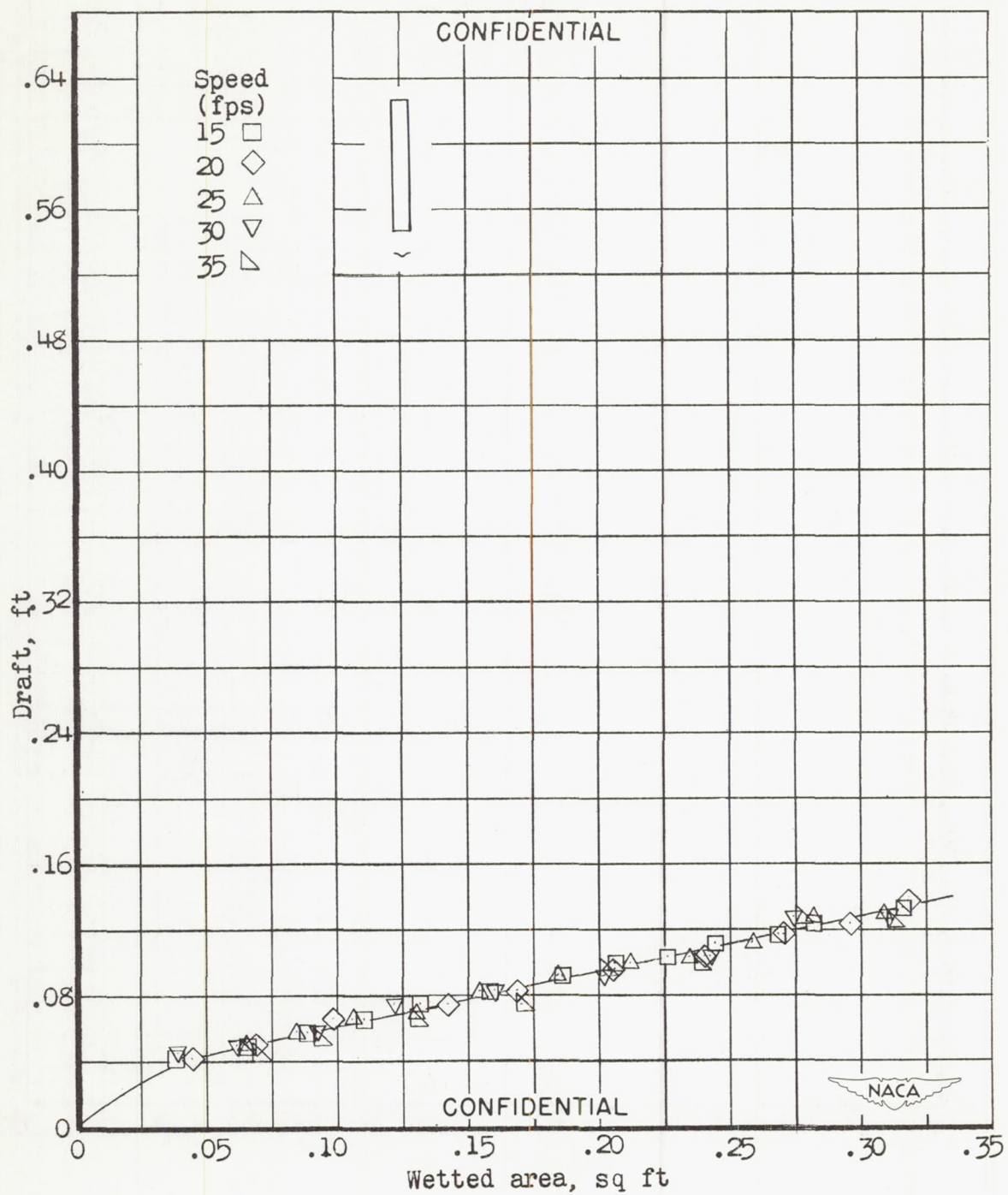
(c) $\tau = 12^\circ$.
Figure 39.- Continued.



(d) $\tau = 16^\circ$.
Figure 39.- Continued.

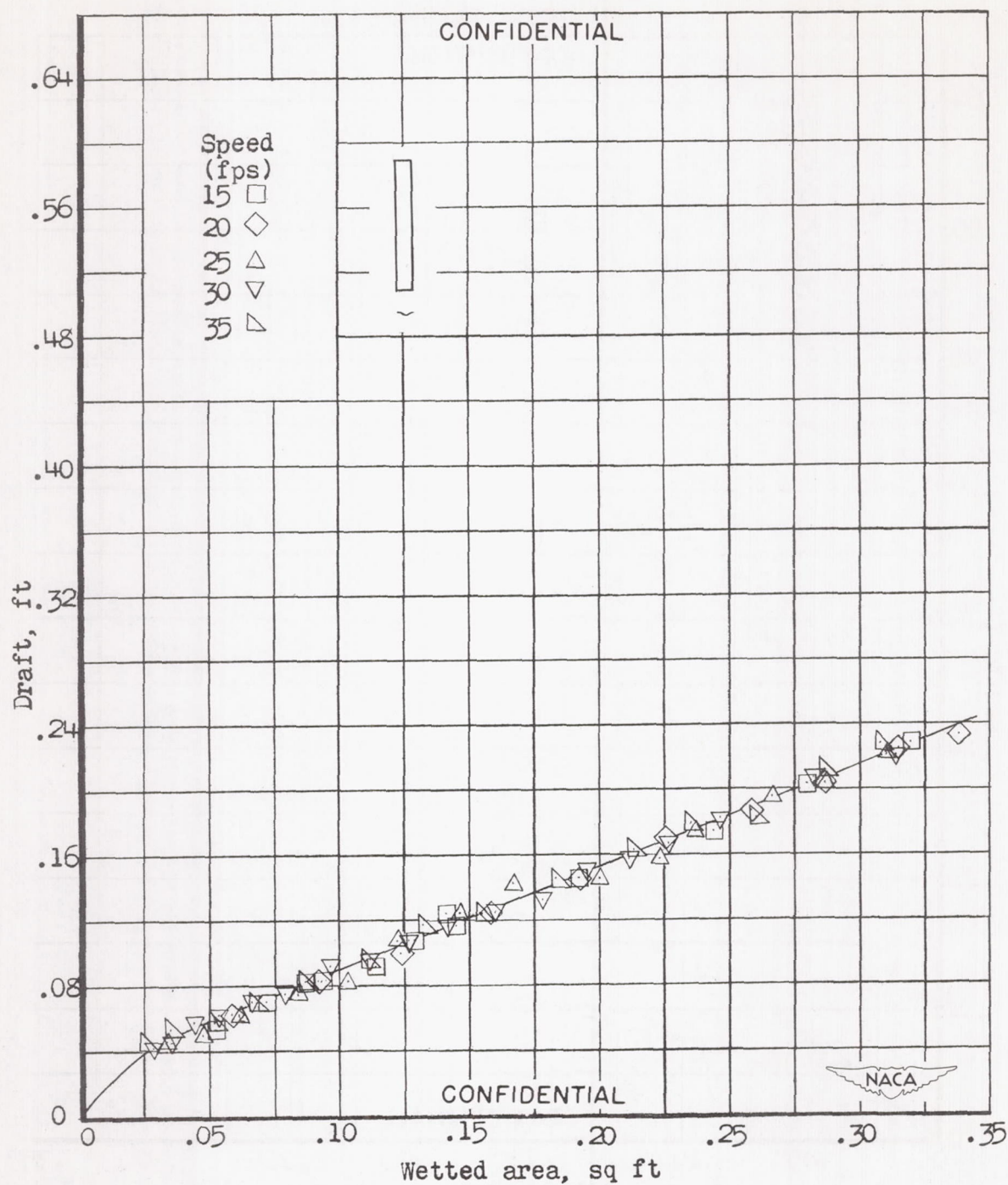


(e) $\tau = 20^\circ$.
Figure 39.- Concluded.



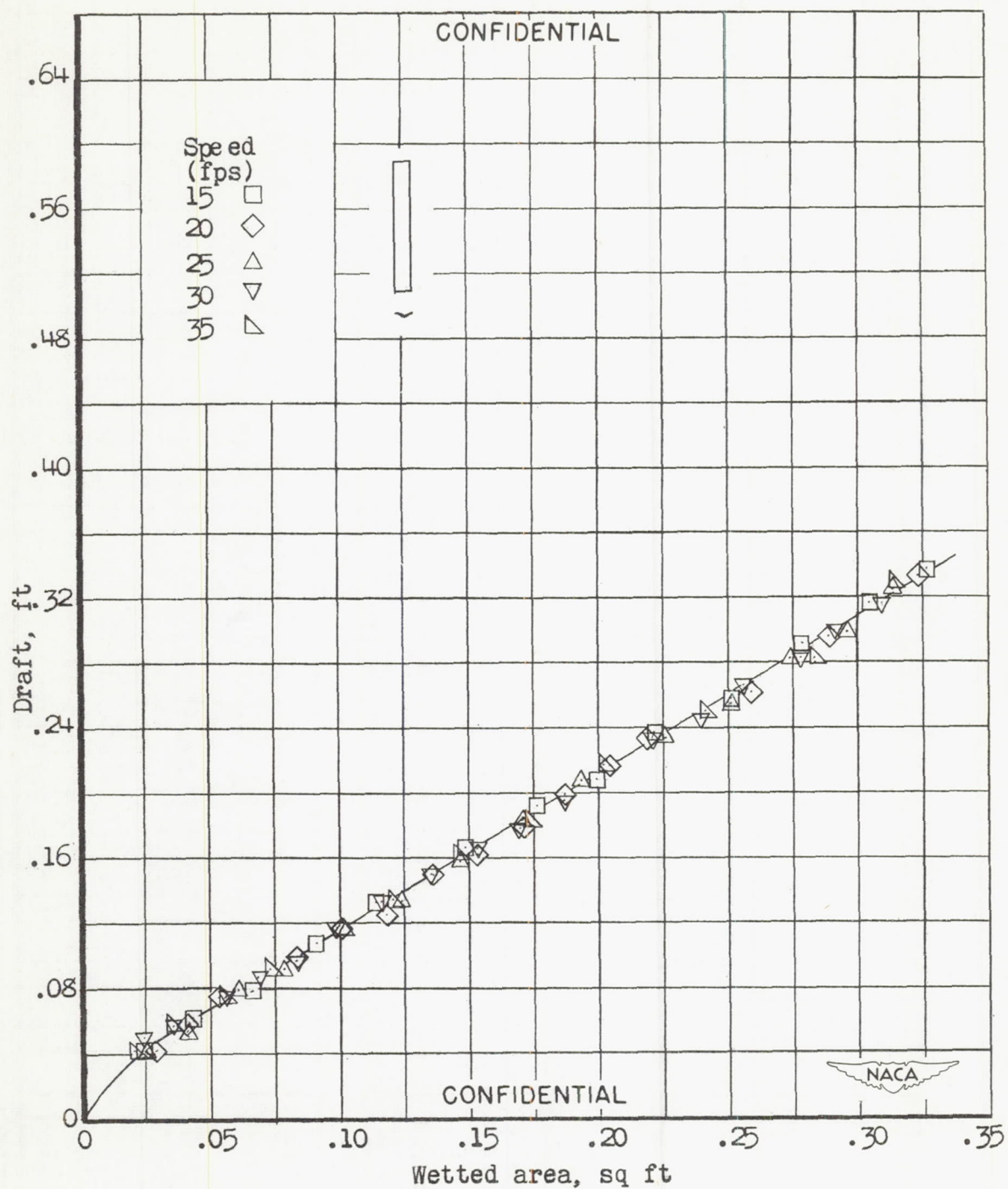
(a) $\tau = 4^\circ$.

Figure 40.- Variation of draft with wetted area. Model 250J.



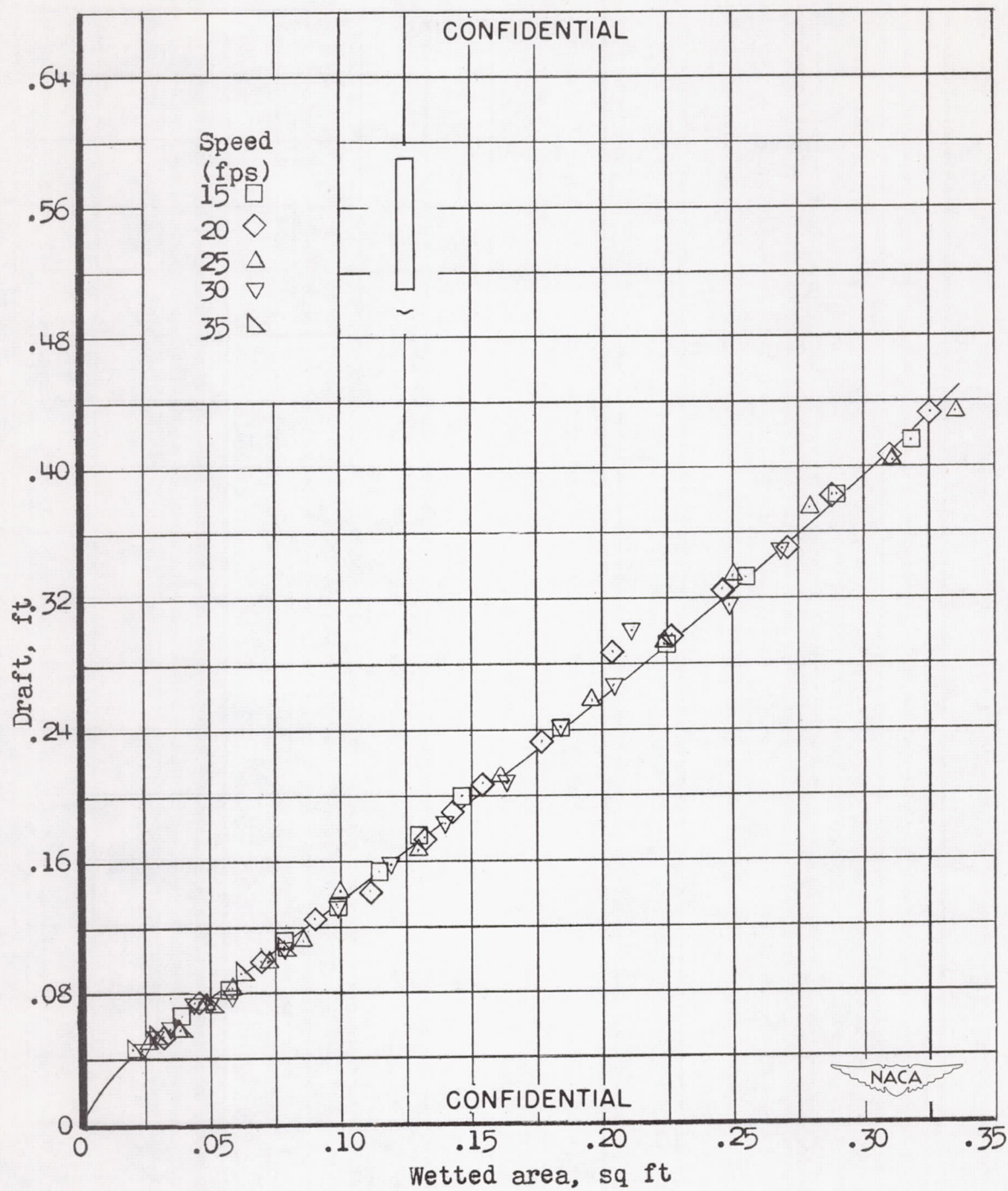
(b) $\tau = 8^\circ$.

Figure 40.- Continued.



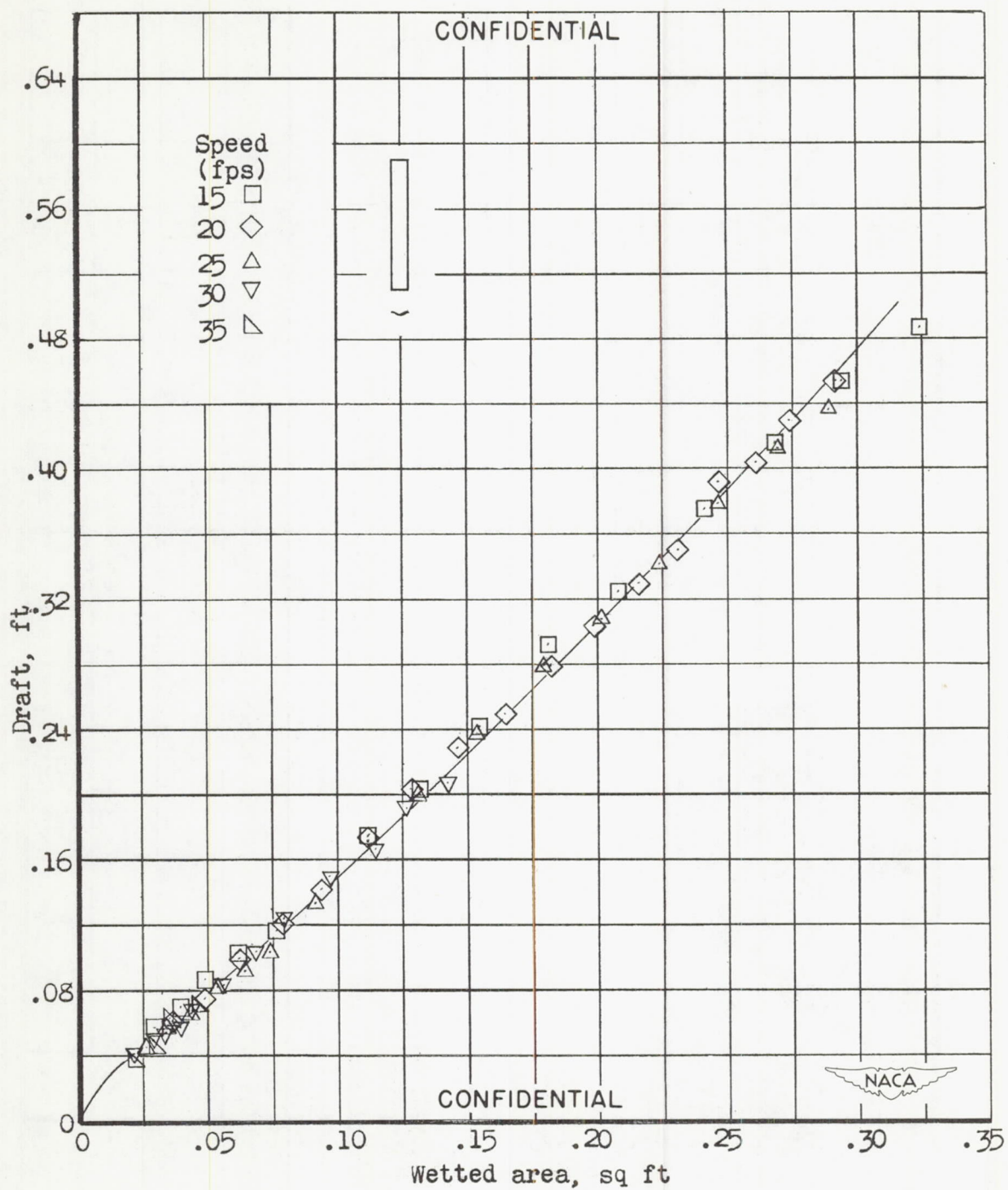
(c) $\tau = 12^\circ$.

Figure 40.- Continued.



(d) $\tau = 16^\circ$.

Figure 40.- Continued.



(e) $\tau = 20^\circ$.

Figure 40.- Concluded.